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Akkumulator-Kraftstoffeinspritzvorrichtung und Steuerungsverfahren

Dispositif et procédé de commande d'injection de combustible du type à accumulation

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- **PATENT ABSTRACTS OF JAPAN vol. 018, no. 360 (M-1634), 7 July 1994 (1994-07-07) & JP 06 093915 A (NIPPONDENSO CO LTD; OTHERS: 01), 5 April 1994 (1994-04-05)**
- **PATENT ABSTRACTS OF JAPAN vol. 017, no. 465 (M-1468), 25 August 1993 (1993-08-25) & JP 05 106495 A (NIPPONDENSO CO LTD), 27 April 1993 (1993-04-27)**

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Description

BACKGROUND OF THE INVENTION

5 1Field of the Invention

[0001] The present invention relates to an accumulator fuel injection control apparatus and method for an internal combustion engine and, more particularly, to an accumulator fuel injection control apparatus and method for an internal combustion engine that is capable of improving precision of fuel injection control in a state of transition.

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2Description of the Related Art

[0002] In general, in an internal combustion engine equipped with an accumulator line such as a common rail or the like, high-pressure fuel is force-fed from a fuel pump to the accumulator line and injected from fuel injection valves connected to the accumulator line into combustion chambers of the engine. In controlling the fuel injection amount, a fuel pressure in the accumulator line is first detected as a fuel injection pressure, and a required injection amount is calculated as an operation state of the engine. Then, a command value for determining a valve-open period of the fuel injection valves is set based on the fuel pressure and the required injection amount. By driving the fuel injection valves based on the command value, the fuel injection valves inject fuel of an amount equal to the required injection amount.

[0003] If the fuel pressure in the accumulator line rises, for example, due to force-feeding of fuel by the fuel pump during a period from the aforementioned detection of the fuel pressure to the start of fuel injection, fuel injection is performed based on a fuel pressure that is higher than the fuel pressure at the time of setting of the command value. Accordingly, the amount of fuel actually injected from the fuel injection valves exceeds the required injection amount. If such a discrepancy between the actual fuel injection amount and the required injection amount becomes too great, problems such as deterioration in exhaust properties and the like arise.

[0004] Hence, as described in the related art such as Japanese Patent Application Laid-Open No. HEI6-93915, the difference between a value of fuel pressure detected last time and a value of fuel pressure detected the second last time is added to the value detected last time during a transitional operation state of the engine, and a fuel injection period (a command value) is set based on the added value and the required fuel injection amount. That is, the change in fuel pressure during a period from detection of a fuel pressure to the start of fuel injection is predicted based on a record of such change, and the predicted value is used in setting a fuel injection period instead of an actual measurement value. As a result, the fuel injection period can be set suitably by preliminarily taking into account a change in fuel pressure during a period from detection of a fuel pressure to the start of fuel injection. Thus, even at the time of transitional operation of the engine, the fuel injection amount can be controlled with high precision.

[0005] However, according to such previously employed fuel injection control, the change in fuel pressure that occurs after detection of a fuel pressure is predicted based on a record of change in fuel pressure. Thus, the detected value of fuel pressure hardly changes and remains substantially constant. Still, in the case where the fuel pressure changes drastically during a period between respective detection timings, the change in fuel pressure can no longer be predicted. As a matter of course, there is no countermeasure to take against such circumstances.

[0006] Further, in a transitional operation state where the operating conditions change abruptly, the fuel injection pressure also changes abruptly. Thus, at the time of an abrupt change in operating conditions, a predictive value, which preliminarily takes into account a change in fuel injection pressure between a timing for actual measurement of fuel injection pressure and a timing for fuel injection by the injectors, is used to calculate a fuel injection amount.

[0007] However, there is an error between the predictive value and the actual measurement value because of a discrepancy in prediction resulting from environmental conditions. Thus, if the predictive value is used despite the fact that there is an actual measurement value available immediately before fuel injection at the time of transition, the precision in fuel injection control amount decreases, which may adversely affect exhaust emissions, noise and the like.

[0008] In order to inhibit such a decrease in precision of fuel injection control, it may be possible to extremely shorten a period from detection of a fuel pressure to the start of fuel injection, for example, by detecting a fuel pressure immediately before the start of fuel injection. However, in reality, there is a need to calculate a control command value for driving the fuel injection valves during that period. In terms of a calculation load and the like, the period cannot be shortened limitlessly.

[0009] In other words, when an attempt is made to always make use of an actual measurement value of fuel injection pressure so as to enhance a precision in calculation of a fuel injection control amount, if there is no sufficient time between the timing for fuel injection by the injectors and the timing for measuring an actual measurement value of fuel injection pressure, the actual measurement value of fuel injection pressure cannot be reflected on fuel injection control. In order to solve this problem, it may be possible to adopt a method wherein the timing for measuring an actual measurement value of fuel injection pressure is changed depending on the operating conditions (i.e. the fuel injection timing),

namely, wherein the timing for measuring an actual measurement value of fuel injection pressure is advanced in proportion to an advancement of the fuel injection timing.

[0010] However, according to this method, if the timing for measuring an actual measurement value of fuel injection pressure is advanced, the measurement is actually carried out during a pump force-feed stroke, so that the fuel injection pressure during the pump force-feed stroke is obtained. In this case, the fuel injection pressure during the pump force-feed stroke is different from the fuel injection pressure at the time of the start of fuel injection. Therefore, if the timing for measuring an actual measurement value of fuel injection pressure is advanced, the precision in fuel injection control amount decreases.

[0011] Furthermore, if the timing for measuring an actual measurement value of fuel injection pressure is changed depending on the operating conditions, namely, on the fuel injection timing, the overall control becomes complicated.

[0012] In conclusion, according to the previously employed fuel injection control, it is impossible to set a fuel injection period that is suited to equalize an actual fuel injection amount with a required injection amount. Therefore, the decrease in precision of fuel injection control is inevitable.

SUMMARY OF THE INVENTION

[0013] It is an object of the present invention to provide an accumulator fuel injection control apparatus and method that is simple and exhibits high precision of fuel injection control at the time of transition.

[0014] The accumulator fuel injection control apparatus according to the present invention is provided with detection means for detecting a fuel pressure in an accumulator line, estimation means for estimating a pressure of fuel injected into an engine, fuel injection control amount calculation means for calculating a fuel injection control amount based on the detected fuel pressure or on the estimated fuel pressure, and fuel injection means for injecting fuel into the engine based on the calculated fuel injection control amount. The gist of the present invention is that the fuel injection control amount calculation means determines which of the detected fuel pressure and the estimated fuel pressure is to be used, based on a fuel injection timing of the injection means.

[0015] As a result, at the time of transition, the frequency with which fuel injection control is performed using indefinite predictive values can be reduced, and the precision of fuel injection control can be enhanced.

[0016] Further, the object of the invention is also solved by the method according to claim 12.

[0017] Although this summary does not describe all the features of the present invention, it should be understood that any combination of the features stated in the dependent claims is within the scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1 is a structural view of an accumulator fuel injection control apparatus for an internal combustion engine according to a first embodiment of the present invention.

Fig. 2 is a graph illustrating a relationship between fuel injection timing and timing for measuring an actual measurement value of fuel injection pressure in the case where the actual measurement value is used to calculate a fuel injection amount.

Fig. 3 is a graph illustrating a relationship between fuel injection timing and timing for measuring an actual measurement value of fuel injection pressure in the case where a predictive value is used to calculate a fuel injection amount.

Fig. 4 is a flowchart showing a process of calculating a fuel injection amount.

Fig. 5 is a flowchart showing a process of calculating a predictive value of fuel injection pressure.

Fig. 6 is a schematic structural view of a high-pressure fuel injection system of a diesel engine according to a second embodiment of the present invention.

Fig. 7 is a timing chart showing a pattern of change in fuel injection pressure caused by leakage of fuel or the like.

Fig. 8 is a timing chart showing a pattern of change in fuel injection pressure caused by force-feeding of fuel and the like.

Fig. 9 is a flowchart showing a process of calculating a fuel injection period according to the second embodiment.

Fig. 10 is a flowchart showing a process of calculating an amount of change in pressure according to the second embodiment.

Fig. 11 is a graph showing fuel pressure and fuel injection amount in relation to fuel injection period.

Fig. 12 is a graph showing fuel pressure and required injection amount in relation to sensitivity coefficient.

Fig. 13 is a flowchart showing a process of calculating a fuel injection period according to a third embodiment of the present invention.

Fig. 14 is a flowchart showing a process of calculating a fuel injection period according to a fourth embodiment of

the present invention.

Fig. 15 is a flowchart showing a process of calculating an amount of change in pressure according to the fourth embodiment.

Fig. 16 is a timing chart showing a pattern of change in fuel injection pressure caused by pilot injection, main injection and the like.

Fig. 17 is a flowchart showing part of a process of calculating an amount of change in pressure according to a fifth embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0019] Embodiments of the present invention will be described hereinafter with reference to the drawings.

[First Embodiment]

[0020] Fig. 1 schematically shows a structure of an accumulator fuel injection control apparatus for an internal combustion engine according to the present invention. In an engine 1 (a four-cylinder engine in this case), injectors 2 for injecting high-pressure fuel to combustion chambers of respective cylinders are disposed. Fuel injection from the injectors 2 to the engine 1 is controlled by opening and closing injection control electromagnetic valves 3. The injectors 2 are connected to a common rail 4 that is commonly used for the respective cylinders. While the injection control electromagnetic valves 3 are open, fuel in the common rail 4 is injected from the injectors 2 into the combustion chambers of the engine 1.

[0021] Because the fuel pressure in the common rail is a fuel injection pressure, the common rail 4 needs to accumulate a suitable fuel pressure corresponding to an operation state. For this reason, a high-pressure pump 7 that is capable of supplying high-pressure fuel is connected to the common rail 4 through a feed line 6 and a check valve 5. The check valve 5 allows fuel to flow only in a direction from the high-pressure pump 7 to the common rail 4.

[0022] A pressure sensor 14 detects an injection pressure of fuel injected from the injector 2 into the combustion chamber of the engine 1, namely, a fuel pressure (rail pressure) in the common rail.

[0023] The high-pressure pump 7 force-feeds a required amount of fuel, which has been sucked from a fuel tank 8 through a low-pressure feed pump 9, to the common rail 4 by reciprocating two plungers (not shown) through a cam (not shown) that synchronizes with rotation of the engine 1. This cam has a lift characteristic of two different phases (see Figs. 2 and 3).

[0024] The high-pressure pump 7 is equipped with two discharge amount control devices 10 corresponding to the two plungers. Each of the discharge amount control devices 10 is equipped with a high-pressure pump valve (not shown) for opening and closing an intake port of the high-pressure pump 7. This high-pressure pump valve adjusts an effective force-feed stroke of the high-pressure pump 7 and controls a discharge amount. By controlling this discharge amount, the pressure in the common rail is determined based on a difference between an amount of fuel discharged from the common rail through fuel injection and an amount of fuel supplied from the high-pressure pump.

[0025] Operations of the injection control electromagnetic valves 3 and the high-pressure pump valves of the discharge amount control devices 10 are controlled by a control signal outputted from an electronic control unit (hereinafter referred to simply as "ECU") 11. Detection signals from an engine rotational speed sensor 12 and an accelerator opening degree sensor 13 are inputted to the ECU 11. Also, input signals from the pressure sensor 14 and various sensors for detecting coolant temperature, intake air temperature, intake air pressure and the like are inputted to the ECU 11. The ECU 11 determines an operation state of the engine based on those input signals, performs an arithmetic processing according to a predetermined program, and outputs optimal control signals for the injection control electromagnetic valves 3 and the discharge amount control devices 10. Although not shown, the ECU 11 is equipped with memories (RAM, ROM) for storing detected data, control programs and the like. The ECU 11 is equipped with a fuel injection amount calculating portion 21 and a fuel injection pressure predictive value calculating portion 22, which will be described later.

[0026] Figs. 2 and 3 are graphs illustrating a relationship between fuel injection timing and timing for measuring an actual measurement value of fuel injection pressure. Fig. 2 shows a case where the actual measurement value is used to calculate a fuel injection amount. Fig. 3 shows a case where a predictive value is used to calculate a fuel injection amount.

[0027] The rail pressure rises due to force-feeding of fuel by the pump in a range indicated by hatched zones in Figs. 2 and 3, after having fallen due to a decrease in amount of fuel in the rail resulting from fuel injection.

[0028] The pressure sensor 14 detects a pressure (a rail pressure P2 in Fig. 3) of fuel injected into the combustion chambers of the engine 1 from the injectors 2 at a first timing t1.

[0029] At a timing t120, the fuel injection amount calculating portion 21 calculates a second timing t2 for start of fuel injection by the injectors 2 from an operation state of the engine. In this case, there are two fuel injection pulses as

pilot injection and main injection are taken into account. The fuel injection amount calculating portion 21 compares a first time T1 corresponding to a difference between the first timing t1 and the second timing t2 with a second time T2 required for the arithmetic processing of a fuel injection amount based on an actual measurement value of fuel injection pressure detected at the first timing t1.

[0030] As shown in Fig. 2, if the arithmetic processing of fuel injection amount based on an actual measurement value of fuel injection pressure measured at the first timing t1 is in time for the second timing t2 which is a timing of fuel injection by the injectors 2, namely, if the first time T1 > the second time T2, the fuel injection amount calculating portion 21 calculates a fuel injection amount at the second timing t2, using a result of the arithmetic processing of the actual measurement value of fuel injection pressure detected at the first timing t1. Thus, in comparison with the case where a predictive value is always used, the precision of fuel injection control is enhanced.

[0031] As shown in Fig. 3, if the arithmetic processing of fuel injection amount based on an actual measurement value of fuel injection pressure measured at the first timing t1 is not in time for the second timing t2 which is a timing of fuel injection by the injectors 2, namely, if the first time T1 < the second time T2, the fuel injection pressure predictive value calculating portion 22 calculates, at a timing t_{exp} , a predictive value of fuel injection pressure at the first timing t1 based on an actual measurement value of fuel injection pressure in a preceding cycle (a rail pressure P1 in Fig. 3). On the other hand, the fuel injection amount calculating portion 21 calculates a fuel injection amount at the second timing t2, using the predictive value calculated by the fuel injection pressure predictive value calculating portion 22.

[0032] The result of calculation of injection control at the timing t_{exp} is used to calculate a fuel injection amount during pilot injection. The calculation of injection control is performed also at the first timing t1. The result of calculation of injection control at the first timing t1 is used to calculate a fuel injection amount during main injection. At the time when the fuel injection amount during main injection has been calculated, a timing when the actual measurement value can be utilized is reached. Thus, the actual measurement value of fuel injection pressure is used.

[0033] Conversely, in the case shown in Fig. 2, the calculations of injection control for pilot injection and main injection are processed altogether. For both pilot injection and main injection, the latest actual measurement value of fuel injection pressure is used for calculation.

[0034] In this manner, the fuel injection amount calculating portion 21 determines which of the actual measurement value and the predictive value of fuel injection pressure is to be used to calculate a fuel injection amount, based on the first time T1 between the first timing t1 and the second timing t2 and on the second time T2 required for the arithmetic processing of a fuel injection amount derived from the actual measurement value of fuel injection pressure measured at the first timing t1.

[0035] As shown in Fig. 3, if a crank angle corresponding to a fuel injection timing of the injectors 2 is advanced, the second timing t2 is advanced with respect to a timing (t1+T2) where the arithmetic processing of fuel injection amount based on the actual measurement value of fuel injection pressure is terminated. Therefore, the actual measurement value cannot be used.

[0036] Fig. 4 is a flowchart for calculating fuel injection pressure and performing an arithmetic processing of fuel injection amount, in a fuel injection control routine that is executed every time a crank shaft rotates by a predetermined angle.

[0037] First of all, the fuel injection amount calculating portion 21 determines whether or not a timing t120 for calculating a second timing t2 where the injectors 2 inject fuel has been reached (S41). If it is determined that the timing t120 has been reached, the process proceeds to S42. If it is determined that the timing t120 has not been reached, the process proceeds to S47.

[0038] In S42, the fuel injection amount calculating portion 21 calculates a second timing t2 where the injectors 2 inject fuel, based on an operational condition of the engine and the like. Depending on the operational condition of the engine, the fuel injection amount calculating portion 21 also determines whether fuel injection is to be carried out once or twice (so-called pilot injection).

[0039] Then, the fuel injection amount calculating portion 21 determines whether or not a timing (t1+T2) after the lapse of the time T2 required for calculation of a fuel injection amount from the first timing t1 when an actual measurement value of fuel injection pressure is obtained is advanced with respect to the second timing t2, which is a fuel injection timing (S43). Herein, it is also possible to calculate a fuel injection timing and a time required for calculation of fuel injection amount every time and compare them. However, if the time required for calculation of fuel injection amount is substantially constant regardless of an operation state of the engine, the determination can be made on the basis of a difference between a fuel injection timing and a timing of actual measurement of fuel injection pressure. Furthermore, if the timing of actual measurement of fuel injection pressure is also constant regardless of an operation state of the engine, the determination can be made only on the basis of what timing the crank angle at the timing of fuel injection corresponds to.

[0040] If the result is YES in S43, the process proceeds to S45 where the fuel injection amount calculating portion 21 sets a flag off.

[0041] On the contrary, if the result is NO in S43, the process proceeds to S44 where the flag is set on. Then, the

fuel injection amount calculating portion 21 calculates a fuel injection amount at the second timing t_2 using a predictive value of fuel injection pressure calculated by the fuel injection pressure predictive value calculating portion 22 (S46). The step S46 corresponds to an operation performed at the timing t_{exp} shown in Fig. 3. A concrete method of calculating a predictive value in this step will be described later with reference to Fig. 5.

[0042] After it is determined in S41 that the timing t_{120} has not been reached (NO), or after the flag has been set off as a result of the determination made in S43 (S45); or after the fuel injection amount at the second timing t_2 has been calculated using the predictive value (S46), the fuel injection amount calculating portion 21 determines whether or not a first timing when the pressure sensor 14 detects an injection pressure of fuel injected into the combustion chambers of the engine 1 from the injectors 2 has been reached (S47).

[0043] If it is determined that the first timing has been reached, the pressure sensor 14 detects a fuel injection pressure of fuel injected into the combustion chambers of the engine 1 from the injectors 2 (S48). If not, the process skips the step of measuring a fuel injection pressure and the step of calculating a fuel injection amount based on an actual measurement value of fuel injection pressure, and proceeds to a step of performing fuel injection (not shown) or the like in the present routine. The detection of fuel injection pressure in S48 includes performing A/D conversion of an analog output of the sensor 14 and retrieving the converted output into the ECU 11.

[0044] Then, the fuel injection amount calculating portion 21 determines whether or not the flag has been set off (S49). If it is determined that the flag has been set off, the fuel injection amount calculating portion 21 calculates a fuel injection amount using a result of the arithmetic processing of the actual measurement value of fuel injection pressure calculated in S48 (S50).

[0045] After the result has been determined as NO in S49, or after the processing in S50 has been terminated, the process proceeds to the step of performing fuel injection (not shown) or the like in the present routine.

[0046] Fig. 5 is a flowchart showing a process of calculating a predictive value of fuel injection pressure used in S46.

[0047] First of all, the fuel injection pressure predictive value calculating portion 22 calculates a pump force-feed amount P_p , of the high-pressure pump 7 based on a fuel intake amount, a fuel temperature, an engine rotational speed and a fuel injection pressure P_{pre} in a preceding cycle (S51).

[0048] Then, the fuel injection pressure predictive value calculating portion 22 calculates an injector leakage amount P_r based on a period of supply of electricity, a fuel temperature, an engine rotational speed and a rail pressure P_{pre} in a preceding cycle (S52). The injector leakage amount as mentioned herein refers to an amount of fuel that is discharged (mainly fuel injection) through the injectors from the common rail 4.

[0049] After that, the fuel injection pressure predictive value calculating portion 22 calculates a volume elasticity coefficient K_p of the fuel in the common rail 4 based on a fuel temperature and a rail pressure P_{pre} in a preceding cycle (S53).

[0050] By means of the respective parameters calculated in the aforementioned steps, it is calculated how much fuel has been supplied to and discharged from a predetermined volume of the common rail 4 after a preceding measurement of fuel pressure. As a result, it is possible to calculate an amount of change in fuel amount since a preceding measurement of fuel pressure. The changed amount of fuel causes a change in fuel pressure in the common rail 4. In this case, with the influence of a volume elasticity of fuel in the common rail being taken into account, a final fuel pressure P_{exp} in the common rail ($P_{exp} = P_{pre} + (P_p - P_r) \times K_p / V_r$) is predicted (S54).

[0051] As described hitherto, according to the present embodiment, the fuel injection amount calculating portion 21 calculates a fuel injection amount using an actual measurement value of fuel injection pressure when the first time T_1 is longer than the second time T_2 , and calculates a fuel injection amount using a predictive value of fuel injection pressure when the first time T_1 is equal to or shorter than the second time T_2 . Accordingly, even if the timing for measuring a fuel injection pressure is not changed, the fuel injection amount can be calculated using an actual measurement value of fuel injection pressure to a possible extent. Thus, the frequency with which the control is performed using an indefinite predictive value at the time of transition is reduced. Consequently, the precision of fuel injection control is enhanced, and it is possible to make use of a predictive value corresponding to the fuel injection timing.

[0052] Further, since the timing for fuel injection is directly compared with the timing for termination of control, the frequency with which the actual measurement value of fuel injection pressure can be used is enhanced.

[0053] In the present embodiment, it may be determined based on an engine rotational speed which of an actual measurement value and a predictive value is to be used to calculate a fuel injection amount.

[0054] The time for a crank angle during high-speed rotation of the engine is shorter than the time for that crank angle during low-speed rotation of the engine. While the timing (t_1) for actual measurement of fuel injection pressure and the timing (t_2) for fuel injection are set as crank angles, the time (T_2) for calculation of fuel injection amount is determined as a time instead of a crank angle. Hence, even if the timing (t_1) for actual measurement of fuel injection pressure and the timing (t_2) for fuel injection correspond to the same crank angle, the time (T_1) from the timing (t_1) for detection of fuel pressure to the timing (t_2) for fuel injection may differ depending on an engine rotational speed. Thus, sometimes, the relationship in length between T_1 and T_2 changes.

[0055] When calculating a fuel injection amount based on an engine rotational speed, the step of determining whether

or not the engine rotational speed is lower than a predetermined value N1 may be carried out instead of S43 of the flowchart shown in Fig. 4.

[0056] If it is determined that the engine rotational speed is lower than N1[rpm], the process proceeds to S45 where the flag is set off. If it is determined that the engine rotational speed is equal to or higher than N1[rpm], the process proceeds to S45 where the fuel injection amount calculating portion 21 sets the flag on.

[0057] The rotational speed N1 as mentioned herein can be selected arbitrarily. It is preferable to select a rotational speed across which the frequency, with which the fuel injection timing when the value obtained by time-converting a difference in crank angle between the timing for measuring fuel pressure (tl in Figs. 2, 3) and the timing for fuel injection by a rotational speed at that time exceeds the time required for calculation of fuel injection amount is set, changes.

[0058] If the fuel injection amount is calculated in this manner, the actual measurement value and the predictive value are distinguished from each other only by determining whether or not a detection signal from the engine rotational speed sensor 12 is at a level lower than a predetermined rotational speed. Therefore, the arithmetic load applied to the ECU can be reduced.

[0059] As described hitherto, it is possible to calculate a fuel injection amount using an actual measurement value of fuel injection pressure to a possible extent. Besides, it is also possible to reduce an arithmetic load applied to the ECU.

[0060] Further, it is also possible to distinguish between an actual measurement value of fuel injection pressure and a predictive value of fuel injection pressure by referring not only to a rotational speed but also to a two-dimensional map of rotational speed and fuel injection timing and the like.

[0061] As described hitherto, the present embodiment makes it possible to provide an accumulator fuel injection control apparatus which exhibits a good precision of fuel injection control at the time of transition.

[Second Embodiment]

[0062] Fig. 6 schematically shows an engine 110 and a high-pressure fuel injection system thereof.

[0063] This high-pressure fuel injection system is equipped with injectors 112 provided so as to correspond to respective cylinders #1 through #4 of the engine 110, a common rail 120 to which the respective injectors 112 are connected, a fuel pump 130 for force-feeding the fuel in a fuel tank 114 to the common rail 120, and an ECU 160.

[0064] A relief valve 122 is attached to the common rail 120. The relief valve 122 is connected to the fuel tank 114 through a relief passage 121. If the fuel pressure (rail pressure) inside the common rail exceeds a predetermined upper limit value, the relief valve 122 is opened so as to reduce the pressure.

[0065] The injectors 112, which are electromagnetic valves that are opened and closed by the ECU 160, inject the fuel supplied from the common rail 120 into combustion chambers (not shown) of the respective cylinders #1 through #4. The respective injectors 112 are also connected to the fuel tank 114 through the relief passage 21. Even when all the injectors 112 are closed, part of the fuel supplied from the common rail 120 to the respective injectors 112 constantly leaks into the injectors 112. The fuel that has thus leaked is returned to the fuel tank 114 through the relief passage 121.

[0066] The ECU 160 performs control relating to force-feeding of fuel by the fuel pump 130 and fuel injection by the injectors 112. The ECU 160 is composed of a memory 164 for storing various control programs, functional data and the like, a CPU 162 for performing various arithmetic processings, and the like.

[0067] Also, various sensors for detecting an operation state of the engine 110 and a state of fuel in the common rail 120 and the like are connected to the ECU 160. Detection signals from those sensors are inputted to the ECU 160.

[0068] For example, a rotational speed sensor 165 is provided in the vicinity of a crank shaft (not shown) of the engine 110, and a cylinder discriminating sensor 66 is provided in the vicinity of a cam shaft (not shown). Based on detection signals inputted from the respective sensors 165, 166, the ECU 160 calculates a rotational speed of the crank shaft (an engine rotational speed NE) and a rotational angle of the crank shaft (a crank angle CA).

[0069] Further, an accelerator sensor 167 is provided in the vicinity of an accelerator pedal (not shown) and detects a detection signal corresponding to a depression amount of the accelerator pedal (an accelerator opening degree ACCP). The common rail 120 is provided with a fuel pressure sensor 168, which outputs a detection signal corresponding to a fuel pressure (an actual fuel pressure PCR). A fuel temperature sensor 169 is provided in the vicinity of a discharge port 38 of the fuel pump 130. The fuel temperature sensor 169 outputs a detection signal corresponding to a temperature of fuel (a fuel temperature THF). The ECU 160 detects an accelerator opening degree ACCP, an actual fuel pressure PCR and a fuel temperature THF based on detection signals from the respective sensors 167 through 169.

[0070] The fuel pump 130 is equipped with a drive shaft 140 rotationally driven by the crank shaft of the engine 110, a feed pump 131 operating based on rotation of the drive shaft 140, a pair of supply pumps driven by an annular cam 142 formed on the drive shaft 140 (a first supply pump 150a and a second supply pump 150b), and the like.

[0071] The feed pump 131 sucks fuel in the fuel tank 114 from an intake port 134 through an intake passage 124, and supplies the fuel to the first supply pump 150a and the second supply pump 150b at a predetermined feed pressure. Out of the fuel that has been sucked from the intake port 134, the surplus fuel that is supplied to neither the first supply pump 150a nor the second supply pump 150b is returned to the fuel tank 114 from a relief port 136 through the relief

passage 121.

[0072] Both the first supply pump 150a and the second supply pump 150b are pumps of an inner cam type. These pumps pressurize the fuel supplied from the feed pump 131 to a higher pressure (e.g. 25 to 180MPa) based on reciprocating movements of a plunger (not shown), and force-feed the pressurized fuel to the common rail 120 from a discharge port 138 through a discharge passage 123. The supply pumps 150a, 150b perform such a force-feed operation of fuel alternately and intermittently.

[0073] The fuel pump 130 is provided with first and second adjusting valves 170a, 170b for adjusting amounts of fuel force-fed from the supply pumps 150a, 150b respectively. Both the adjusting valves 170a, 170b are designed as electromagnetic valves that are driven by the ECU 160 to be opened and closed.

[0074] Fig. 7 is a timing chart showing timings for sucking fuel through and force-feeding fuel from the respective supply pumps 150a, 150b, a pattern of change in fuel injection pressure resulting from fuel leakage, and the like.

[0075] The respective supply pumps 150a, 150b alternately suck fuel into the fuel pump 30 with phases in crank angle CA (CA: Crank Angle) being offset from each other by 180°CA. Likewise, the respective supply pumps 150a, 150b alternately force-feed fuel from the fuel pump 130 with phases being offset from each other by 180°CA.

[0076] As indicated by (c) in Fig. 7, the first adjusting valve 70a is opened during an intake stroke of the first supply pump 150a so as to start sucking fuel, and is closed at a predetermined timing (crank angle CA) so as to stop sucking fuel. All the fuel that has been thus sucked is pressurized in a force-feed stroke which follows the intake stroke, and is force-fed from the first supply pump 150a to the common rail 120. The amount of fuel force-fed from the first supply pump 150a can be adjusted by changing a timing for closing the first adjusting valve 170a.

[0077] For example, as indicated by alternate long and short dash lines in (c) and (d), if the timing (crank angle CA) for closing the first adjusting valve 70a is retarded to thereby increase an open-valve period thereof, the period of sucking fuel through the first supply pump 150a is prolonged. Thus, as a result of an increase in fuel intake amount, the amount of fuel force-fed increases. Further, if the timing for closing the first adjusting valve 170a is thus retarded, the timing (crank angle CA) for starting force-feeding fuel from the first supply pump 150a is advanced by a crank angle equal to the amount of retardation. As a result, the period of force-feeding fuel is prolonged.

[0078] On the other hand, as indicated by alternate long and two short dashes lines in (c) and (d), if the timing for closing the first adjusting valve 170a is advanced to thereby reduce an open-valve period thereof, the period of sucking fuel through the first supply pump 150a is shortened. Thus, as a result of a decrease in fuel intake amount, the amount of fuel force-fed decreases. Further, if the timing for closing the first adjusting valve 170a is thus advanced, the timing for starting force-feeding fuel from the first supply pump 150a is retarded by a crank angle CA equal to the amount of advancement. As a result, the period of force-feeding fuel is shortened.

[0079] Likewise, by retarding or advancing a timing (crank angle CA) for closing a second adjusting valve 70b, the amount of fuel force-fed from the second supply pump 150b can be changed. Further, the timing for starting force-feeding fuel from the second supply pump 150b is advanced or retarded by a crank angle equal to the amount of retardation or advancement of a closed-valve period thereof.

[0080] The timings for starting sucking fuel through and finishing force-feeding fuel from the respective supply pumps 150a, 150b are set to constant timings (crank angles CA). The timings for starting force-feeding fuel from the respective supply pumps 150a, 150b can be calculated based on open-valve periods of the respective adjusting valves 170a, 170b. The amounts of fuel force-fed from the respective supply pumps 150a, 150b per unit crank angle CA (hereinafter referred to as "fuel force-feed rate KQPUMP") are equal to each other and always constant regardless of the timings for starting force-feeding fuel. Accordingly, the total amounts of fuel force-fed from the respective supply pumps 150a, 150b during the force-feed periods can be calculated by multiplying the force-feed periods by the fuel force-feed rate KQPUMP.

[0081] The ECU 60 sets a target pressure of fuel injection pressure based on an operation state of the engine. Based on a difference between the target pressure and an actual fuel pressure PCR detected by a fuel pressure sensor 68, the ECU 60 controls the aforementioned adjusting valves 170a, 170b such that the fuel injection pressure becomes equal to the target pressure.

[0082] For example, if the actual fuel pressure PCR is lower than the target pressure, the fuel injection pressure is raised by retarding timings for opening the respective adjusting valves 170a, 170b and increasing an amount of fuel force-fed. On the other hand, if the actual fuel pressure PCR is higher than the target pressure, the fuel injection pressure is prevented from rising by advancing timings for closing the respective adjusting valves 170a, 170b and reducing an amount of fuel force-fed, and the fuel injection pressure is reduced through fuel injection.

[0083] By performing such fuel pressure control, the fuel injection pressure is adjusted to a pressure suited for an operation state of the engine.

[0084] Further, the ECU 160 calculates a required injection amount based on an operation state of the engine, and calculates a fuel injection period (an open-valve period) based on the required injection amount and the fuel injection pressure (the actual fuel pressure PCR). Based on the thus-calculated fuel injection period, the injectors 12 are driven by the ECU 60 to be opened and closed.

[0085] Herein, the value of fuel injection pressure when calculating a fuel injection period, namely, the actual fuel pressure PCR detected by the fuel pressure sensor 168 does not always coincide with the value of fuel injection pressure at the time of start of fuel injection.

[0086] For example, as described above, the fuel in the common rail 120 constantly leaks out to the fuel tank 114 through the injectors 112. Thus, as shown in Fig. 7, the fuel injection pressure PCRINJ at the time of start of fuel injection may become lower than the actual fuel pressure PCR due to the leakage of fuel. Alternatively, as shown in Fig. 8, if the force-feed period of the fuel pump 130 is prolonged and force-feeding of fuel is started prior to the start of fuel injection, the fuel injection pressure PCRINJ at the time of start of fuel injection may become higher than the actual fuel pressure PCR due to the force-feeding of fuel.

[0087] In the present embodiment, a change in fuel injection pressure from detection of the actual fuel pressure PCR to the start of fuel injection is estimated, and the change in fuel injection pressure is reflected on calculation of a fuel injection period.

[0088] Control processes relating to such fuel injection will be described hereinafter with reference to Figs. 9 through 12.

[0089] Figs. 9 and 10 are flowcharts showing processes of calculating a fuel injection period. The ECU 160 carries out a series of processes shown in those respective flowcharts as an interrupt handling at intervals of a predetermined crank angle (180°CA).

[0090] First of all, in step 100, the ECU 60 detects an actual fuel pressure PCR. As shown in Figs. 7 and 8, the timing when the actual fuel pressure PCR is detected, namely, the timing when the present routine interrupts is set to a timing when the respective supply pumps 150a, 150b are switched from an intake stroke to a force-feed stroke (a timing when the crank angle CA reaches angles CA0, CA1, CA2 and CA3 shown in the respective drawings).

[0091] In step 200, a required injection amount QFIN is calculated based on an accelerator opening degree ACCP, an engine rotational speed NE and the like. Then in step 300, a basic injection period TQFINB is calculated based on the required injection amount QFIN and the actual fuel pressure PCR. The required injection amount QFIN and the actual fuel pressure PCR in relation to the basic injection period TQFINB are calculated preliminarily through experiments and the like and stored into the memory 164 of the ECU 160 as functional data for calculating the basic injection period TQFINB.

[0092] Fig. 11 shows the functional data in the form of a functional map. The basic injection period TQFINB is calculated as a period that becomes longer in proportion to an increase in required injection amount QFINB and a decrease in actual fuel pressure PCR.

[0093] Then in step 400, the ECU 60 calculates a pressure change amount DPCR. The pressure change amount DPCR is an amount of change in fuel pressure resulting from force-feeding of fuel or leakage of fuel during a period from detection of the actual fuel pressure PCR (CA0 through CA3 in Figs. 7 and 8) to the start of fuel injection by the injectors 112 (crank angle interval: see (a) in Fig. 7 and (a) in Fig. 8)(the period will be referred to hereinafter as a "pressure change estimation period APCR").

[0094] Fig. 10 is a flowchart showing in detail a process of calculating a pressure change amount DPCR. In step 402, the ECU 160 calculates a force-feed period APUMP. The force-feed period APUMP (see (a) in Fig. 8) is a period (crank angle interval) where fuel is force-fed during the pressure change estimation period APCR.

[0095] First of all, when calculating the force-feed period APUMP, the ECU 160 calculates a force-feed starting period of the fuel pump 130 based on timings for closing the respective adjusting valves 170a, 170b as set during an intake stroke prior to the present start of force-feeding of fuel. For example, if the present timing for interruption coincides with a timing CA1 shown in Fig. 8, the force-feed starting period is calculated based on the valve-closing periods that are set during a period from CA0 to CA1. Likewise, if the timing for interruption coincides with a timing CA2, the force-feed starting period is calculated based on the valve-closing periods that are set during a period from CA1 to CA2.

[0096] Then, the ECU 160 compares the force-feed starting timing with a fuel injection starting timing that is separately calculated. If the force-feed starting timing is retarded with respect to the fuel injection starting timing, namely, unless force-feeding of fuel is carried out prior to the start of fuel injection, the force-feed period APUMP is calculated as zero. On the other hand, if the force-feed starting timing is advanced with respect to the fuel injection starting period, namely, if force-feeding of fuel is started prior to the start of fuel injection, the period between the fuel injection starting timing and the force-feed starting timing is calculated as the force-feed period APUMP.

[0097] After the force-feed period APUMP has been thus calculated, the ECU 160 calculates in step 404 a fuel force-feeding amount QPUMP during the pressure change estimation period APCR according to a calculation formula (I) shown below.

$$QPUMP = APUMP \times KQPUMP \quad (1)$$

APUMP: force-feed period

KQPUMP: fuel force-feed rate

[0098] Then, the ECU 160 calculates a fuel leakage period TLEAK. The fuel leakage period TLEAK is obtained by converting the pressure change estimation period APCR, which is expressed as a unit of crank angle, into a time. The ECU 160 calculates the fuel leakage period TLEAK according to a calculation formula (2) shown below.

$$TLEAK = K \times APCR / NE \quad (2)$$

APCR: pressure change estimation period
NE: engine rotational speed
K: conversion constant

[0099] In step 408, a fuel leakage amount QLEAK during the pressure change estimation period APCR is calculated based on the fuel leakage period TLEAK, the actual fuel pressure PCR and the fuel temperature THF. The fuel leakage amount QLEAK tends to increase in proportion to an increase in fuel leakage period TLEAK, an increase in actual fuel pressure PCR and an increase in fuel temperature THF. The fuel leakage period TLEAK, the actual fuel pressure PCR and the fuel temperature THF in relation to the fuel leakage amount QLEAK are preliminarily calculated through experiments and the like and stored into the memory 164 of the ECU 160 as functional data for calculating the fuel leakage amount QLEAK.

[0100] Then in step 410, a volume elasticity coefficient E of fuel is calculated based on the actual fuel pressure PCR and the fuel temperature THF. The volume elasticity coefficient E tends to increase in proportion to an increase in actual fuel pressure PCR and a decrease in fuel temperature THF. The actual fuel pressure PCR and the fuel temperature THF in relation to the volume elasticity coefficient E are preliminarily calculated through experiments and the like and stored into the memory 164 of the ECU 160 as functional data.

[0101] After having thus calculated the fuel force-feed amount QPUMP, the fuel leakage amount QLEAK and the volume elasticity coefficient E, the ECU 60 calculates in step 412 a pressure change amount DPCR according to a calculation formula (3) shown below.

$$DPCR = E \times (QPUMP - QLEAK) / VCR \quad (3)$$

E: volume elasticity coefficient
QPUMP: fuel force-feed amount
QLEAK: fuel leakage amount
VCR: volume of common rail

[0102] As is apparent from the calculation formula (3), if the fuel force-feed amount QPUMP is greater than the fuel leakage amount QLEAK, the pressure change amount DPCR is calculated as a positive value. On the contrary, if the fuel leakage amount QLEAK is greater than the fuel force-feed amount QPUMP, the pressure change amount DPCR is calculated as a negative value.

[0103] After having thus calculated the pressure change amount DPCR, the ECU 160 shifts the processing to step 500 shown in Fig. 9 and calculates a sensitivity coefficient TQPCR based on the required injection amount QFIN and the actual fuel pressure PCR.

[0104] In the case where the fuel injection pressure has changed into a value different from the actual fuel pressure PCR during the pressure change estimation period APCR, if the respective injectors 112 are driven based on the basic injection period TQFINB, the actual fuel injection amount deviates from the required injection amount QFIN. The sensitivity coefficient TQPCR is obtained by converting a fuel injection amount deviating from a unitary change amount at the time of such a change in fuel injection pressure (e.g. 1 MPa) into a deviation amount of fuel injection period.

[0105] The sensitivity coefficient TQPCR and the required injection amount QFIN in relation to the actual fuel pressure PCR are preliminarily calculated through experiments and the like and stored into the memory 164 of the ECU 160 as functional data for calculating the sensitivity coefficient TQPCR. Fig. 12 shows the functional data in the form of a functional map. The sensitivity coefficient TQPCR is calculated as a value that becomes greater in proportion to an increase in required injection amount QFIN and a decrease in actual fuel pressure PCR.

[0106] Then in step 600, the ECU 160 calculates an injection period correction value TQFINH according to a calculation formula (4) shown below.

$$TQFINH = TQPCR \times DPCR \quad (4)$$

TQPCR: sensitivity coefficient

DPCR: pressure change amount

[0107] The injection period correction value TQFINH is a value for correcting the basic injection period TQFINB so as to compensate for a discrepancy between the actual fuel injection amount and the required injection amount QFIN resulting from the above-mentioned change in fuel injection pressure.

[0108] Then in step 700, the ECU 60 calculates a final injection period TQFIN according to a calculation formula (5) shown below.

$$TQFIN = TQFINB \times TQFINH \quad (5)$$

TQFINBT: basic injection period

TQFINH: injection period correction value

[0109] After having thus calculated the final injection period TQFIN, the ECU 160 temporarily terminates the present routine.

[0110] The ECU 160 then produces a drive signal for the injectors 112 based on the final injection period TQFIN and outputs the signal to the injectors 112 at a timing when the crank angle CA coincides with the fuel injection starting timing. As a result, the injectors 112 inject fuel of an amount equal to the required injection amount QFIN.

[0111] As described hitherto, according to the fuel injection control of the present embodiment, the pressure change amount DPCR during the pressure change estimation period APCR is estimated based on the fuel force-feed amount QPUMP and the fuel leakage amount QLEAK. The basic injection period TQFINB, which is corrected by the injection period correction value TQFINH based on the pressure change amount DPCR, is set as the final injection period TQFIN.

[0112] Accordingly, if the fuel injection pressure changes during the pressure change estimation period APCR due to force-feeding of fuel or leakage of fuel, even during stationary operation of the engine where the detected value of fuel injection pressure (the actual fuel pressure PCR) hardly changes, the change amount (the pressure change amount DPCR) can be estimated precisely based on the fuel force-feed amount QPUMP and the fuel leakage amount QLEAK. Besides, the final injection period TQFIN can be set with extremely high precision as a value suited for preventing the actual fuel injection amount from deviating from the required injection amount QFIN based on the pressure change amount DPCR.

[0113] As a result, according to the present embodiment, it is possible to securely reflect a change in fuel injection pressure on fuel injection control even if the change has occurred after detection of the actual fuel pressure PCR. Accordingly, the fuel injection control can be performed with extremely high precision.

[0114] Especially because the fuel force-feed amount QPUMP and the fuel leakage amount QLEAK are referred to in estimating the pressure change amount DPCR, both the rise in fuel injection pressure resulting from force-feeding of fuel and the fall in fuel injection pressure resulting from leakage of fuel can be reflected on estimation of the pressure change amount DPCR. Accordingly, it is possible to inhibit the actual fuel injection amount from becoming greater or smaller than the required injection amount QFIN due to such a rise or fall in fuel injection pressure.

[0115] As a result, it is possible to prevent occurrence of an inconvenience such as deterioration of exhaust properties, which results from the engine 110 being supplied with an excessive amount of fuel that does not suit an operation state of the engine. It is also possible to prevent occurrence of an inconvenience such as a decrease in engine output, which results from the engine 110 not being supplied with a sufficient amount of fuel that suits an operation state of the engine.

[Third Embodiment]

[0116] A third embodiment of the present invention will now be described focusing on a difference between the second and third embodiments. The construction similar to that of the second embodiment will not be described.

[0117] In the present embodiment, the process of calculating the final injection period TQFIN is different from that of the second embodiment.

[0118] The process of calculating the final injection period TQFIN will now be described with reference to a flowchart shown in Fig. 13. Out of the respective steps 100 through 710, those denoted by the same reference numerals as in Fig. 11 refer to the same processings as described above. Therefore, the description of those steps will be omitted.

[0119] After having carried out the respective processings in steps 100, 200, the ECU 160 calculates in step 400 a

pressure change amount DPCR. Then in step 610, the ECU 160 makes a correction by adding the pressure change amount DPCR to an actual fuel pressure PCR and sets a thus-corrected value as a new actual fuel pressure PCR.

[0120] Then in step 710, as in the processing of step 300 shown in Fig. 9, the ECU 160 calculates a final injection period TQFIN based on the renewed actual fuel pressure PCR and the required injection amount QFIN, by referring to the functional data shown in Fig. 11. After having thus calculated the final injection period TQFIN, the ECU 160 temporarily terminates the processings of this routine.

[0121] As described hitherto, according to the present embodiment, in order to inhibit the actual fuel injection amount from deviating from the required injection amount QFIN due to a change in fuel injection pressure, the actual fuel pressure has only to be corrected based on the pressure change amount DPCR prior to calculation of the final injection period TQFIN.

[0122] Accordingly, there is no need to dare to calculate the basic injection period TQFINB and the injection period correction value TQFINH. Also, there is no need to prepare in advance functional data for calculating the injection period correction value TQFINH as shown in Fig. 11 and the like. Thus, the overall control structure can be simplified.

[0123] In the second embodiment and the present embodiment, the pressure change amount DPCR is estimated based on both the fuel-force-feed amount QPUMP and the fuel leakage amount QLEAK. However, the pressure change amount DPCR can also be estimated based only on the fuel force-feed amount QPUMP or only on the fuel leakage amount QLEAK.

[Fourth Embodiment]

[0124] A fourth embodiment of the present invention will now be described focusing on a difference between the second and fourth embodiments.

[0125] In the present embodiment, a fuel injection control apparatus according to the present invention is applied to the engine 110 capable of carrying out pilot injection. As is known, this pilot injection is intended to inhibit an abrupt rise in combustion pressure by preliminarily injecting a small amount of fuel prior to main injection and to thereby reduce the level of combustion noise. According to the fuel injection control of the present embodiment, if the fuel injection pressure falls due to pilot injection, the injection period at the time of main injection (the main injection period TQMAIN) is corrected to an appropriate period based on the amount of decrease in pressure.

[0126] In the present embodiment, the timings for opening the respective adjusting valves 170a, 170b are preliminarily set such that force-feeding of fuel by the fuel pump 130 is always started after termination of main injection (see Fig. 16). Therefore, there is no chance that force-feeding of fuel might be carried out during a period from detection of the actual fuel pressure PCR to termination of main injection, or that the fuel injection pressure might change because of force-feeding of fuel.

[0127] The process of calculating a main injection period TQMAIN will be described hereinafter.

[0128] Figs. 14 and 15 are flowcharts showing processes of calculating a main injection period TQMAIN and a pilot injection period TQPLT. Fig. 16 is a timing chart showing timings for sucking fuel into and force-feeding fuel from the respective supply pumps 150a, 150b and a pattern of change in fuel injection pressure caused by pilot injection, main injection and the like.

[0129] The ECU 60 carries out a series of processings in the respective flowcharts shown in Figs. 14 and 15 as an interrupt handling at intervals of a predetermined crank angle (180 °CA). As is the case with the processing routines shown in Figs. 9 and 13, the timing for interruption of the present routine is set to a timing when the respective supply pumps 50a, 50b are switched from an intake stroke to a force-feed stroke (a timing when the crank angle CA reaches angles CA0, CA1, CA2 and CA3 shown in Fig. 16).

[0130] The ECU 60 detects an actual fuel pressure PCR in steps 100, 200 shown in Fig. 14, and further calculates a required injection amount QFIN based on an accelerator opening degree ACCP, an engine rotational speed and the like.

[0131] In step 320, the ECU 60 calculates a pilot injection amount QPLT based on the engine rotational speed NE and the required injection amount QFIN. The pilot injection amount QPLT in relation to the engine rotational speed NE and the required injection amount QFIN is preliminarily calculated through experiments and the like so as to best suit an operation state of the engine in consideration of combustion noise, a concentration of exhaust gas and the like, and is stored into the memory 64 as functional data for calculating a pilot injection amount QPLT.

[0132] Then in step 330, a main injection amount QMAIN is calculated according to a calculation formula (6) shown below.

$$Q_{MAIN} = Q_{FIN} - Q_{PLT} \quad (6)$$

QFIN: required injection amount

QPLT: pilot injection amount

[0133] After having thus calculated the pilot injection amount QPLT and the main injection amount QMAIN, the ECU 60 calculates in step 450 an amount of change in fuel injection pressure (a pressure change amount DPCRPLT) during a period from detection of the actual fuel pressure PCR to the start of pilot injection (a pressure change estimation period APCRPLT: see Fig. 16) and an amount of change in fuel injection pressure (a pressure change amount DPCRMAIN) during a period from detection of the actual fuel pressure PCR to the start of main injection (a pressure change estimation period APCRMAIN: see Fig. 16).

[0134] Fig. 15 is a flowchart showing a process of calculating the respective pressure change amounts DPCRPLT, DPCRMAIN in detail.

[0135] In step 452, the ECU 160 converts the respective pressure change estimation periods APCRPLT, APCRMAIN into times based on the engine rotational speed NE, and sets the converted values as a fuel leakage period TLEAKPLT from detection of the actual fuel pressure PCR to the start of pilot injection and a fuel leakage period TLEAKMAIN from detection of the actual fuel pressure PCR to the start of main injection respectively.

[0136] As in the processing in step 408 shown in Fig. 10, the ECU 160 calculates in step 454 an amount of leakage of fuel (a fuel leakage amount QLEAKPLT) from detection of the actual fuel pressure PCR to the start of pilot injection and an amount of leakage of fuel (a fuel leakage amount QLEAKMAIN) from detection of the actual fuel pressure PCR to the start of main injection, based on the respective fuel leakage periods TLEAKPLT, TLEAKMAIN, the actual fuel pressure PCR and the fuel temperature THF. Furthermore, as in the processing in step 410 shown in Fig. 10, the ECU 160 calculates in step 456 a volume elasticity coefficient E based on the actual fuel pressure PCR and the fuel temperature THF.

[0137] Then in step 458, the ECU 60 calculates the respective pressure change amounts DPCRPLT, DPCRMAIN according to calculation formulas (7) and (8) shown below.

$$DPCRPLT = QLEAKPLT/VCR \quad (7)$$

$$DPCRMAIN = E \times (QPLT + QLEAKMAIN)/VCR \quad (8)$$

E: volume elasticity coefficient
QLEAKPLT, QLEAKMAIN: fuel leakage amounts
VCR: volume of the common rail 20

[0138] As is apparent from the calculation formula (8), in addition to the fuel leakage amount QLEAKMAIN, the pilot injection amount QPLT is also reflected on calculation of the pressure change amount DPCRMAIN from detection of the actual fuel pressure PCR to the start of main injection. This is because in performing pilot injection, main injection is performed at a fuel injection pressure lower than that of the pilot injection.

[0139] After having thus calculated the respective pressure change amounts DPCRPLT, DPCRMAIN, the ECU 60 shifts the processing to step 620 shown in Fig. 14. In step 620, the ECU 60 calculates a fuel injection pressure at the time of the start of pilot injection (hereinafter referred to as "a pilot injection fuel pressure") PCRPLT and a fuel injection pressure at the time of the start of main injection (hereinafter referred to as "a main injection fuel pressure") PCRMAIN according to calculation formulas (9) and (10) shown below respectively.

$$PCRPLT = PCR - DPCRPLT \quad (9)$$

$$PCRMAIN = PCR - DPCRMAIN \quad (10)$$

PCR: actual fuel pressure
DPCRPLT, DPCRMAIN: pressure change amounts

[0140] As is apparent from these calculation formulas (9) and (10), both the pilot injection fuel pressure PCRPLT and the main injection fuel pressure PCRMAIN are obtained by correcting the actual fuel pressure PCR based on the respective pressure change amounts DPCRPLT and DPCRMAIN respectively.

[0141] Then in step 720, as in the processing of step 710 shown in Fig. 13, the ECU 60 calculates a pilot injection period TQPLT and a main injection period TQMAIN based on the respective fuel pressures PCRPLT, PCRMAIN, the

pilot injection amount QPLT and the main injection amount QMAIN, by referring to the functional data shown in Fig. 11. As a result, the respective injection periods TQPLT, TQMAIN are corrected substantially based on the aforementioned respective fuel pressures PCRPLT, PCRMAIN.

[0142] After having thus calculated the respective injection periods TQPLT, TQMAIN, the ECU 60 temporarily terminates the processings of the present routine.

[0143] As described hitherto, according to the present embodiment, the pilot injection period TQPLT and the main injection period TQMAIN are corrected based on changes in fuel injection pressure from detection of the actual fuel pressure PCR to the start of pilot injection or main injection (the pressure change amounts DPCRPLT, DPCRMAIN).

[0144] Accordingly, the respective injection periods TQPLT, TQMAIN can be set with extremely high precision as values suited for preventing the actual fuel injection amounts during pilot injection and main injection from deviating from the pilot injection amount QPLT and the main injection amount QMAIN respectively. Even in the case where pilot injection is performed, fuel injection control can be performed with extremely high precision.

[0145] Further, the amounts of decrease in fuel injection pressure resulting from leakage of fuel (the pressure change amounts DPCRPLT, DPCRMAIN) are securely estimated, and the respective injection periods TQPLT, TQMAIN are corrected based on the amounts of decrease in fuel injection pressure. Thereby, it becomes possible to inhibit the actual fuel injection amounts during pilot injection and main injection from becoming smaller than the pilot injection amount QPLT and the main injection amount QMAIN as required injection amounts. As a result, it is possible to prevent occurrence of an inconvenience such as a decrease in engine output, which results from the internal concentration engine not being supplied with a sufficient amount of fuel that suits an operation state of the engine.

[0146] Especially, when estimating the pressure change amount DPCRMAIN from detection of the actual fuel pressure PCR to the start of main injection, the amount of decrease in fuel injection pressure resulting from pilot injection as well as leakage of fuel is taken into account. Thus, it is possible to inhibit the fuel injection pressure from falling due to the implementation of pilot injection and to inhibit the actual fuel injection amount during main injection from becoming smaller than the main injection amount QMAIN. Accordingly, in this respect, it is possible to more reliably prevent occurrence of an inconvenience such as a decrease in engine output.

[0147] In the present embodiment, the pressure change amount DPCRMAIN from detection of the actual fuel pressure PCR to the start of main injection is estimated based on the fuel leakage amount QLEAKMAIN and the pilot injection amount QPLT. However, the pressure change amount DPCRMAIN can be estimated based only on the fuel leakage amount QLEAKMAIN or on the pilot injection amount QPLT. However, the pressure change amount DPCRMAIN may also be estimated based only on the fuel leakage amount QLEAKMAIN or on the pilot injection amount QPLT.

[0148] Furthermore, in the case of a construction wherein force-feeding of fuel can be started prior to the start of main injection, a fuel force-feed amount from detection of the actual fuel pressure PCR to the start of main injection may be calculated. The pressure change amount DPCRMAIN may be estimated based on the fuel force-feed amount or on the pilot injection amount QPLT as well as the fuel leakage amount QLEAKMAIN.

[0149] Further, in the present embodiment, the actual fuel pressure PCR is preliminarily corrected based on the respective pressure change amounts DPCRPLT, DPCRMAIN, and the fuel injection periods during pilot injection and main injection (the pilot injection period TQPLT, the main injection period PCRMAIN) are calculated based on the values after such correction (the pilot injection fuel pressure PCRPLT, the main injection fuel pressure PCRMAIN). However, as in the second embodiment, the correction values relating to the pilot injection period TQPLT and the main injection period TQMAIN may be calculated based on the respective pressure change amounts DPCRPLT, DPCRMAIN, and the respective fuel injection periods TQPLT, TQMAIN may be corrected based on those correction values.

[0150] Further, in the aforementioned embodiment, there is shown an example in which pilot injection is performed only once prior to main injection. However, the pilot injection may be performed a plurality of times prior to main injection. In such a case, after pilot injection has been performed more than once, the subsequent pilot injection is performed such that the fuel injection period during that pilot injection is corrected based on a change in fuel injection pressure that is estimated based on a total amount of fuel injection during the previously performed pilot injection.

[Fifth Embodiment]

[0151] A fifth embodiment of the present invention will now be described focusing on a difference between the second and fifth embodiments.

[0152] In the present embodiment, in addition to the change in fuel injection pressure during the pressure change estimation period APCR, the change in fuel injection pressure resulting from force-feeding of fuel or leakage of fuel is estimated. The final injection period TQFIN is further corrected based on the change in fuel injection pressure, whereby the precision of fuel injection control is further enhanced.

[0153] The process of estimating a change in fuel injection pressure during such a fuel injection period and the process of correcting the final injection period TQFIN based on a change in fuel injection pressure will be described

hereinafter.

[0154] Fig. 17 is a flowchart showing a process of estimating a change in fuel injection pressure during the fuel injection period (hereinafter referred to as "a pressure change amount DPCRINJ"). The respective processings shown in this flowchart are carried out following the processing in step 412, as part of a series of processings shown in the flowchart of Fig. 10.

[0155] First of all, in step 420, the ECU 160 adds the actual fuel pressure PCR to the pressure change amount DPCR calculated through the processing in step 412. Based on the sum (PCR+DPCR) and the fuel temperature THF, the ECU 160 again calculates a volume elasticity coefficient E such that the volume elasticity coefficient E corresponds to a value at the time of the start of fuel injection.

[0156] Then in step 422, a fuel leakage amount QLEAKINJ during the fuel injection period is calculated based on the basic injection period TQFINB and the fuel temperature THF. Then in step 424, it is determined whether or not the timing for starting force-feeding fuel from the fuel pump 30 is advanced with respect to the timing for starting fuel injection, namely, whether or not force-feeding of fuel is carried out prior to the start of fuel injection. If it is determined that force-feeding of fuel is carried out prior to the start of fuel injection, fuel is always force-fed during the fuel injection period. Therefore, in step 426, the ECU 60 converts the basic injection period TQFINB into a crank angle CA based on the engine rotational speed NE, and sets the converted value as a force-feed period APUMPINJ during the fuel injection period.

[0157] Then in step 428, a fuel force-feed amount QPUMPINJ during the fuel injection period is calculated according to a calculation formula (11) shown below.

$$QPUMPINJ = APUMPINJ \times KQPUMP \quad (11)$$

APUMPINJ: force-feed period

KQPUMP: fuel force-feed rate

[0158] On the other hand, if it is determined in step 424 that force-feeding of fuel is not carried out prior to the start of fuel injection, the ECU 60 shifts the processing to step 430. In step 430, the ECU 60 calculates a fuel injection termination period based on the fuel injection starting timing, the basic injection timing TQFINB and the engine rotational speed NE, using the crank angle CA as a unit.

[0159] In the subsequent step 432, by comparing the fuel injection termination period with the timing for starting force-feeding fuel from the fuel pump 30, it is determined whether or not force-feeding of fuel is started during the fuel injection period. If it is determined herein that force-feeding of fuel is started during the fuel injection period, a period (crank angle CA) from the force-feed starting timing to the fuel injection termination period is calculated in step 434 as a force-feed period APUMPINJ during the fuel injection period. Then in step 436, a fuel force-feed amount QPUMPINJ during the fuel injection period is calculated according to the aforementioned calculation formula (11).

[0160] On the other hand, if it is determined in step 432 that force-feeding of fuel is not started during the fuel injection period, the force-feed period does not overlap with the fuel injection period. Thus, in step 435, the ECU 60 sets the fuel force-feed amount QPUMPINJ during the fuel injection period to zero.

[0161] After having carried out any of the aforementioned steps 428, 435 and 486, the ECU 60 calculates in step 440 a pressure change amount DPCRINJ during the fuel injection period according to a calculation formula (12) shown below.

$$DPCRINJ = E \times (QPUMPINJ - QLEAKINJ) / VCR \quad (12)$$

E: volume elasticity coefficient

QPUMPINJ: fuel force-feed amount during fuel injection period

QLEAKINJ: fuel leakage amount during fuel injection period

VCR: volume of the common rail 20

[0162] Then in step 442, the ECU 60 calculates an average pressure change amount DPCRAVE based on the already-calculated pressure change amount DPCR during the pressure change estimation period and the pressure change amount DPCRINJ during the aforementioned fuel injection period, according to a calculation formula (13) shown below.

$$DPCRAVE = DPCR + DPCRINJ / 2 \quad (13)$$

[0163] The average pressure change amount DPCRAVE is a mean value of the pressure change amount DPCR from detection of the actual fuel pressure PCR to the start of fuel injection (i.e. during the pressure change estimation period APCR) and the pressure change amount (DPCR+DPCRINJ) from detection of the actual fuel pressure PCR to the termination of fuel injection.

[0164] After the average pressure change amount DPCRAVE has been thus calculated, the processings following step 500 shown in Fig. 9 are carried out. In this case, in the processing in step 600, an injection period correction value TQFINH is calculated based on the aforementioned average pressure change amount DPCRAVE, in place of the pressure change amount DPCR during the pressure change estimation period APCR. Hence, in the subsequent step 700, the basic injection period TQFINB is corrected based on the change in fuel injection pressure (the pressure change amount DPCRINJ) during the fuel injection period as well as the change in fuel injection pressure (the pressure change amount DPCR) during the pressure change estimation period APCR.

[0165] Thus, according to the present embodiment, it is possible not only to inhibit the actual fuel injection amount from deviating from the required injection amount QFIN due to a change in fuel injection pressure from detection of the actual fuel pressure PCR to the start of fuel injection, but also to inhibit deviation of the fuel injection amount resulting from a change in fuel injection pressure during the fuel injection period. As a result, fuel injection control can be performed with much higher precision.

[0166] In particular, when estimating the amount of change in fuel injection pressure during the fuel injection period (the pressure change amount DPCRINJ), the fuel force-feed amount QPUMP and the fuel leakage amount QLEAK are referred to. Thus, both the amount of a rise in fuel injection pressure resulting from force-feeding of fuel and the amount of a fall in fuel injection pressure resulting from leakage of fuel can be reflected on the pressure change amount DPCRINJ. Accordingly, it is possible to inhibit the actual fuel injection amount from becoming greater than the required injection amount QFIN due to a rise in fuel injection pressure, or conversely, to inhibit the actual fuel injection amount from becoming smaller than the required injection amount QFIN due to a fall in fuel injection pressure. As a result, it is possible to prevent occurrence of an inconvenience such as deterioration of exhaust properties, which results from the engine 110 being supplied with an excessive amount of fuel that does not suit an operation state of the engine. It is also possible to prevent occurrence of an inconvenience such as a decrease in engine output, which results from the engine 110 not being supplied with a sufficient amount of fuel that suits an operation state of the engine.

[0167] In the present embodiment, the pressure change amount DPCRINJ during the fuel injection period is estimated based on the fuel force-feed amount QPUMPINJ and the fuel leakage amount QLEAKINJ. However, the pressure change amount DPCRINJ may be estimated based only on the fuel force-feed amount QPUMPINJ or only on the fuel leakage amount QLEAKINJ.

[0168] In the second through fourth embodiments, as in the present embodiment, an amount of change in fuel injection pressure resulting from force-feeding of fuel or leakage of fuel during the pilot injection period or the main injection period may be estimated, and the pilot injection period TQPLT and the main injection period TQMAIN may further be corrected based on the thus-estimated amount of change in fuel injection pressure.

[0169] Further, in the aforementioned second, third and fifth embodiments, the fuel force-feed amount of the fuel pump 30 is calculated on the assumption that the fuel force-feed rate (KQPUMP) is constant. However, for example, even in the case where the fuel force-feed rate changes depending on the timing for starting force-feeding of fuel, the fuel force-feed amount can be calculated by referring to a map or the like that shows the fuel force-feed rate in relation to the timing for starting force-feeding of fuel.

[0170] In the aforementioned second through fifth embodiments, there is shown an example in which the fuel injection amount is controlled based on a fuel injection period, namely, on an open-valve period of the injectors 112. However, for example, the fuel injection amount can be controlled based not only on the open-valve period but also on an opening degree of the injectors 112. In this case, it may be possible to correct a command value for the opening degree of the injectors 112 based on a change in fuel injection pressure.

[0171] In the aforementioned second through fifth embodiments, a diesel engine is shown as an example of an internal combustion engine to which the fuel injection control apparatus of the present invention is applied. However, for example, the present invention can also be applied to a direct-injection gasoline engine wherein fuel is directly injected into combustion chambers.

Claims

1. An accumulator fuel injection control apparatus, **characterized by** comprising:

detection means (14) for detecting a fuel pressure in an accumulator line (4);
estimation means (22) for estimating a pressure of fuel injected into an engine (1); fuel injection control amount calculation means (21) for calculating a fuel injection control amount based on the detected fuel pressure or

on the estimated fuel pressure; and
 fuel injection means for injecting fuel into the engine based on the calculated fuel injection control amount,
 wherein
 the fuel injection control amount calculation means (21) determines which of the detected fuel pressure and
 the estimated fuel pressure is to be used, based on a fuel injection timing of the injection means.

2. The accumulator fuel injection control apparatus according to claim 1, **characterized in:**

that the detection means (14) detects a fuel pressure at a first timing (t1);
that the fuel injection means (2) injects fuel at a second timing (t2) that is later than the first timing; and
that the injection control amount calculation means (21) calculates the fuel injection control amount based on
 the detected fuel pressure, if an arithmetic processing of the fuel pressure detected at the first timing is com-
 pleted earlier than the second timing.

3. The accumulator fuel injection control apparatus according to claim 2, **characterized in:**

that the fuel injection control amount calculation means (21) determines which of the detected fuel pressure
 and the estimated fuel pressure is to be used, based on a first time (T1) from the first timing (t1) to the second
 timing (t2) and on a second time (T2) required for the arithmetic processing.

4. The accumulator fuel injection control apparatus according to claim 3, **characterized in:**

that the fuel injection control amount calculation means (21) calculates the fuel injection control amount using
 the detected fuel pressure, if the first time (T1) is longer than the second time (T2).

5. The accumulator fuel injection control apparatus according to claim 1, **characterized in:**

that the fuel injection control amount calculation means (21) determines which of the detected fuel pressure
 and the estimated fuel pressure is to be used to calculate the fuel injection control amount, based on a rotational
 speed of the engine (1).

6. The accumulator fuel injection control apparatus according to claim 5, **characterized in:**

that the fuel injection control amount calculation means (21) calculates the fuel injection control amount using
 the detected fuel pressure, if the rotational speed of the engine (1) is lower than a predetermined value.

7. The accumulator fuel injection control apparatus according to claim 1, **characterized in:**

that the estimation means (22) calculates the fuel pressure based on an operation state of a pump (7) for
 supplying the fuel to the accumulator line (14) and on a volume elasticity coefficient of the fuel.

8. The accumulator fuel injection control apparatus according to claims 1 to 7, **characterized in:**

that the fuel injection control amount is a fuel injection amount.

9. The accumulator fuel injection control apparatus according to claim 1, **characterized in:**

that the estimation means (22) estimates the fuel pressure based on a force-feed amount of fuel by the pump
 (7) for supplying the fuel to the accumulator line (14) during a period from detection of the fuel pressure to
 start of fuel injection.

10. The accumulator fuel injection control apparatus according to claim 1, **characterized in:**

that the estimation means (22) estimates the fuel pressure based on an amount of fuel leaking out from the
 accumulator line (14).

11. The accumulator fuel injection control apparatus according to claims 1 to 10, **characterized in:**

that the estimation means (22) estimates a fuel pressure based on a change in fuel pressure during a period of fuel injection.

12. A method for controlling a fuel injection, **characterized by** the steps:

5 detecting a fuel pressure in an accumulator line (4);
estimating a pressure of fuel injected into an engine (1);
calculating a fuel injection control amount based on the detected fuel pressure or on the estimated fuel pressure; and
10 injecting fuel into the engine based on the calculated fuel injection control amount, with the further step:
determining which of the detected fuel pressure and the estimated fuel pressure is to be used, based on a fuel injection timing of an injection means.

13. The method according to claim 12, **characterized by**:

15 detecting a fuel pressure at a first timing (t1);
injecting fuel at a second timing (t2) that is later than the first timing; and
calculating the fuel injection control amount based on the detected fuel pressure, if an arithmetic processing of the fuel pressure detected at the first timing is completed earlier than the second timing.

14. The method according to claim 13, **characterized by**:

20 determining which of the detected fuel pressure and the estimated fuel pressure is to be used, based on a first time (T1) from the first timing (t1) to the second timing (t2) and on a second time (T2) required for the arithmetic processing.

15. The method according to claim 14, **characterized by**:

30 calculating the fuel injection control amount using the detected fuel pressure, if the first time (T1) is longer than the second time (T2).

16. The method according to claim 12, **characterized by**:

35 determining which of the detected fuel pressure and the estimated fuel pressure is to be used to calculate the fuel injection control amount, based on a rotational speed of the engine (1).

17. The method according to claim 16, **characterized by**:

40 calculating the fuel injection control amount using the detected fuel pressure, if the rotational speed of the engine (1) is lower than a predetermined value.

18. The method according to claim 12, **characterized by**:

45 calculating the fuel pressure based on an operation state of a pump (7) for supplying the fuel to the accumulator line (14) and on a volume elasticity coefficient of the fuel.

19. The method according to claims 12 to 18, **characterized in**:

50 that the fuel injection control amount is a fuel injection amount.

20. The method according to claim 12, **characterized by**:

55 estimating the fuel pressure based on a force-feed amount of fuel by a pump (7) for supplying the fuel to the accumulator line (14) during a period from detection of the fuel pressure to start of fuel injection.

21. The method according to claim 12, **characterized by**:

estimating the fuel pressure based on an amount of fuel leaking out from the accumulator line (14).

22. The method according to claims 12 to 21, **characterized by:**

estimating a fuel pressure based on a change in fuel pressure during a period of fuel injection.

5

Patentansprüche

1. Akkumulator-Brennstoffeinspritzsteuergerät, **gekennzeichnet durch:**

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eine Detektoreinrichtung (14), um einen Brennstoffdruck in einer Sammelleitung (4) zu detektieren;

eine Schätzeinrichtung (22) zum Schätzen eines Druckes des Brennstoffes, der in eine Maschine (1) eingespritzt wird;

15

eine Berechnungseinrichtung (21) für den Brennstoffeinspritzsteuerbetrag, um einen Brennstoffeinspritzsteuerbetrag basierend auf dem detektierten Brennstoffdruck oder basierend auf dem geschätzten Brennstoffdruck zu berechnen; und

20

eine Brennstoffeinspritzeinrichtung zum Einspritzen des Brennstoffes in die Maschine basierend auf dem berechneten Brennstoffeinspritzsteuerbetrag, wobei

die Berechnungseinrichtung (21) für den Brennstoffeinspritzsteuerbetrag bestimmt, welche der Größen gemäß dem detektierten Brennstoffdruck und dem geschätzten Brennstoffdruck zu verwenden ist und zwar basierend auf einer Brennstoffeinspritzzeitsteuerung der Einspritzeinrichtung.

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2. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 1, **dadurch gekennzeichnet, daß**

die Detektoreinrichtung (14) einen Brennstoffdruck bei einer ersten Zeitlage (t1) detektiert; die Brennstoffeinspritzeinrichtung (2) den Brennstoff bei einer zweiten Zeitlage (t2) einspritzt, die später liegt als die erste Zeitlage; und

30

die Berechnungseinrichtung (21) für den Einspritzsteuerbetrag den Brennstoffeinspritzsteuerbetrag basierend auf dem detektierten Brennstoffdruck berechnet, wenn eine arithmetische Verarbeitung des bei der ersten Zeitlage detektierten Brennstoffdruckes früher vervollständigt wird als der zweiten Zeitlage.

3. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 2, **dadurch gekennzeichnet, daß**

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die Berechnungseinrichtung (21) für den Brennstoffeinspritzsteuerbetrag bestimmt, welche der Größen gemäß dem detektierten Brennstoffdruck und dem geschätzten Brennstoffdruck zu verwenden ist, basierend auf einer ersten Zeit (T1) von der ersten Zeitlage (t1) bis zur zweiten Zeitlage (t2) hin, und auf der Grundlage einer zweiten Zeit (T2), die für die arithmetische Verarbeitung erforderlich ist.

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4. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 3, **dadurch gekennzeichnet, daß**

die Berechnungseinrichtung (21) für den Brennstoffeinspritzsteuerbetrag den Brennstoffeinspritzsteuerbetrag unter Verwendung des detektierten Brennstoffdruckes berechnet, wenn die erste Zeit (T1) länger ist als die zweite Zeit (T2).

45

5. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 1, **dadurch gekennzeichnet, daß**

die Berechnungseinrichtung (21) für den Brennstoffeinspritzsteuerbetrag bestimmt, welche der Größen gemäß dem detektierten Brennstoffdruck und dem geschätzten Brennstoffdruck zu verwenden ist, um den Brennstoffeinspritzsteuerbetrag zu berechnen und zwar basierend auf einer Drehzahl der Maschine (1).

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6. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 5, **dadurch gekennzeichnet, daß**

die Berechnungseinrichtung (21) für den Brennstoffeinspritzsteuerbetrag den Brennstoffeinspritzsteuerbetrag unter Verwendung des detektierten Brennstoffdruckes berechnet, wenn die Drehzahl der Maschine (1) niedriger ist als ein vorbestimmter Wert.

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7. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 1, **dadurch gekennzeichnet, daß**

die Schätzeinrichtung (22) den Brennstoffdruck basierend auf einem Betriebszustand einer Pumpe (7) berechnet, um den Brennstoff der Sammelleitung (14) zuzuführen, und auf der Grundlage eines Volumen-Elastizitätskoeffizienten des Brennstoffes berechnet.

8. Akkumulator-Brennstoffeinspritzsteuergerät nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet, daß** der Brennstoffeinspritzsteuerbetrag eine Brennstoffeinspritzmenge ist.
- 5 9. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 1, **dadurch gekennzeichnet, daß** die Schätzeinrichtung (22) den Brennstoffdruck basierend auf einer Zwangsfördermenge an Brennstoff durch die Pumpe (7) schätzt, um den Brennstoff der Sammelleitung (14) während einer Periode vom Detektieren des Brennstoffdruckes an bis zum Start der Brennstoffeinspritzung zuzuführen.
- 10 10. Akkumulator-Brennstoffeinspritzsteuergerät nach Anspruch 1, **dadurch gekennzeichnet, daß** die Schätzeinrichtung (22) den Brennstoffdruck basierend auf einer Brennstoffmenge schätzt, die aus der Akkumulatorleitung (14) herausleckt.
- 15 11. Akkumulator-Brennstoffeinspritzsteuergerät nach einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet, daß** die Schätzeinrichtung (22) einen Brennstoffdruck basierend auf einer Änderung im Brennstoffdruck während einer Periode der Brennstoffeinspritzung schätzt.
12. Verfahren zum Steuern einer Brennstoffeinspritzung, **gekennzeichnet durch** die folgenden Schritte:
 - 20 Detektieren eines Brennstoffdruckes in einer Sammelleitung (4);
 - Schätzen des Druckes des Brennstoffes, der in eine Maschine (1) eingespritzt wird;
 - Berechnen eines Brennstoffeinspritzsteuerbetrages basierend auf dem detektierten Brennstoffdruck oder auf den geschätzten Brennstoffdruck; und
 - 25 Einspritzen des Brennstoffes in die Maschine basierend auf dem berechneten Brennstoffeinspritzsteuerbetrag mit dem folgenden Schritt:
 - 30 Bestimmen, welche der Größen gemäß dem detektierten Brennstoffdruck und dem geschätzten Brennstoffdruck zu verwenden ist und zwar basierend auf einer Brennstoffeinspritzzeitlage einer Einspritzeinrichtung.
13. Verfahren nach Anspruch 12, **gekennzeichnet durch** die folgenden Schritte:
 - 35 Detektieren eines Brennstoffdruckes zu einer ersten Zeitlage (t1);
 - Injizieren von Brennstoff bei einer zweiten Zeitlage (t2), die später liegt als die erste Zeitlage; und
 - 40 Berechnen des Brennstoffeinspritzsteuerbetrages basierend auf dem detektierten Brennstoffdruck, wenn eine arithmetische Verarbeitung des Brennstoffdruckes, der zu der ersten Zeitlage detektiert wird, früher vervollständigt wird als die zweite Zeitlage.
14. Verfahren nach Anspruch 13, **gekennzeichnet durch** die folgenden Schritte:
 - 45 Bestimmen, welche der Größen gemäß dem detektierten Brennstoffdruck und dem geschätzten Brennstoffdruck zu verwenden ist basierend auf einer ersten Zeit (T1) von der ersten Zeitlage (t1) an bis zu der zweiten Zeitlage (t2) hin, und basierend auf einer zweiten Zeit (T2), die für die arithmetische Verarbeitung erforderlich ist.
- 50 15. Verfahren nach Anspruch 14, **gekennzeichnet durch** den folgenden Schritt:
 - Berechnen des Brennstoffeinspritzsteuerbetrages unter Verwendung des detektierten Brennstoffdruckes, wenn die erste Zeit (T1) länger ist als die zweite Zeit (T2).
- 55 16. Verfahren nach Anspruch 12, **gekennzeichnet durch** die folgenden Schritte:
 - Bestimmen, welche der Größen gemäß dem detektierten Brennstoffdruck und dem geschätzten Brennstoffdruck zum Berechnen des Brennstoffeinspritzsteuerbetrages zu verwenden ist und zwar basierend auf einer

Drehzahl der Maschine (1).

17. Verfahren nach Anspruch 16, **gekennzeichnet durch**:

5 Berechnen des Brennstoffeinspritzsteuerbetrages unter Verwendung des detektierten Brennstoffdruckes, wenn die Drehzahl der Maschine (1) niedriger liegt als ein vorbestimmter Wert.

18. Verfahren nach Anspruch 12, **gekennzeichnet durch** die folgenden Schritte:

10 Berechnen des Brennstoffdruckes basierend auf einem Betriebszustand einer Pumpe (7) zum Zuführen von Brennstoff zu der Sammelleitung (14) und basierend auf einen Volumen-Elastizitätskoeffizienten des Brennstoffes.

15 19. Verfahren nach einem der Ansprüche 12 bis 18, **dadurch gekennzeichnet, daß** der Brennstoffeinspritzsteuerbetrag aus einer Brennstoffeinspritzmenge besteht.

20. Verfahren nach Anspruch 12, **gekennzeichnet durch** den folgenden Schritt:

20 Schätzen des Brennstoffdruckes basierend auf einer Zwangsfördermenge an Brennstoff **durch** eine Pumpe (7) zum Zuführen des Brennstoffes zu der Sammelleitung (14) während einer Periode vom Detektieren des Brennstoffdruckes an bis zum Start der Brennstoffeinspritzung hin.

21. Verfahren nach Anspruch 12, **gekennzeichnet durch** den folgenden Schritt:

25 Schätzen des Brennstoffdruckes basierend auf einer Menge des Brennstoffes, der aus der Sammelleitung (14) herausleckt.

22. Verfahren nach einem der Ansprüche 12 bis 21, **gekennzeichnet durch** den folgenden Schritt:

30 Schätzen eines Brennstoffdruckes basierend auf einer Änderung in dem Brennstoffdruck während einer Periode der Brennstoffeinspritzung.

Revendications

35

1. Appareil de commande d'injection de carburant à accumulateur comprenant :

un moyen de détection (14) pour détecter une pression de carburant sur une ligne d'accumulateur (4) ;
un moyen d'estimation (22) pour estimer une pression de carburant injecté dans un moteur (1) ;
40 un moyen de calcul de quantité de commande d'injection de carburant (21) pour calculer une quantité de commande d'injection de carburant basée sur la pression de carburant détectée ou sur la pression de carburant estimée ; et
un moyen d'injection de carburant pour injecter le carburant dans le moteur basé sur la quantité de commande d'injection de carburant calculée dans lequel
45 le moyen de calcul de la quantité de commande d'injection de carburant (21) détermine laquelle de la pression de carburant détectée et de la pression de carburant estimée doit être utilisée, basée sur un temps d'injection de carburant du moyen d'injection.

50 2. Appareil de commande d'injection de carburant à accumulateur selon la revendication 1, **caractérisé en ce que** :

le moyen de détection (14) détecte une pression de carburant à un premier instant (t1) ;
le moyen d'injection de carburant (2) injecte le carburant à un deuxième instant (t2) qui est postérieur au premier instant ; et
le moyen de calcul de la quantité de commande d'injection (21) calcule la quantité de commande d'injection
55 de carburant basée sur la pression de carburant détectée, si un traitement arithmétique de la pression de carburant détectée au premier instant se termine plus tôt que le deuxième instant.

3. Appareil de commande d'injection de carburant à accumulateur selon revendication 2, **caractérisé en ce que** :

le moyen de calcul de la quantité de commande d'injection de carburant (21) détermine laquelle de la pression de carburant détectée ou de la pression de carburant estimée doit être utilisée, basée sur un premier temps (T1) à partir du premier instant (t1) au deuxième instant (t2) et sur un deuxième temps (T2) nécessaire pour le traitement arithmétique.

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4. Appareil de commande d'injection de carburant à accumulateur selon revendication 3, **caractérisé en ce que** :

le moyen de calcul de la quantité de commande d'injection de carburant (21) calcule la quantité de commande d'injection de carburant utilisant la pression de carburant détectée, si le premier temps (T1) est supérieur au deuxième temps (T2).

10

5. Appareil de commande d'injection de carburant à accumulateur selon revendication 1, **caractérisé en ce que** :

le moyen de calcul de la quantité de commande d'injection de carburant (21) détermine laquelle de la pression de carburant détectée ou de la pression de carburant estimée doit être utilisée pour calculer la quantité de commande d'injection de carburant, basée sur la vitesse de rotation du moteur (1).

15

6. Appareil de commande d'injection de carburant à accumulateur selon revendication 5, **caractérisé en ce que** :

le moyen de calcul de la quantité de commande d'injection de carburant (21) calcule la quantité de commande d'injection de carburant utilisant la pression de carburant détectée, si la vitesse de rotation du moteur (1) est inférieure à une valeur prédéterminée.

20

7. Appareil de commande d'injection de carburant à accumulateur selon revendication 1, **caractérisé en ce que** :

le moyen d'estimation (22) calcule la pression de carburant basée sur un état de fonctionnement d'une pompe (7) d'alimentation du carburant sur la ligne d'accumulateur (14) et sur un coefficient d'élasticité volumique de carburant.

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8. Appareil de commande d'injection de carburant à accumulateur selon les revendications 1 à 7, **caractérisé en ce que** :

la quantité de commande d'injection de carburant est une quantité d'injection de carburant.

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9. Appareil de commande d'injection de carburant à accumulateur selon la revendication 1, **caractérisé en ce que** :

le moyen d'estimation (22) estime la pression de carburant basée sur la quantité de carburant à alimentation forcée par la pompe (7) pour alimenter le carburant dans la ligne d'accumulateur (14) pendant une période allant de la détection de la pression du carburant au début de l'injection du carburant.

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10. Appareil de commande d'injection du carburant à accumulateur selon la revendication 1, **caractérisé en ce que** :

le moyen d'estimation (22) estime la pression du carburant basée sur une quantité de carburant fuyant de la ligne d'accumulateur (14).

40

11. Appareil de commande d'injection de carburant à accumulateur selon les revendications 1 à 10, **caractérisé en ce que** :

le moyen d'estimation (22) estime une pression de carburant basée sur un changement de pression de carburant pendant une période d'injection de carburant.

45

12. Procédé de commande d'injection de carburant **caractérisé par** les étapes consistant à :

détecter une pression de carburant dans une ligne d'accumulateur (4) ;
estimer une pression de carburant injectée dans un moteur (1) ;
calculer une quantité de commande d'injection de carburant basée sur la pression de carburant détectée ou sur la pression de carburant estimée ; et
injecter le carburant dans le moteur, basé sur la quantité de commande d'injection de carburant calculée, avec

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une autre étape consistant à :

déterminer laquelle de la pression de carburant détectée et de la pression de carburant estimée doit être utilisée, en se basant sur un moment d'injection de carburant d'un moyen d'injection.

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13. Procédé selon la revendication 12, **caractérisé par** les étapes consistant à :

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détecter une pression de carburant lors d'un premier instant (t1) ;
injecter le carburant lors d'un deuxième instant (t2) qui est postérieur au premier instant ; et
calculer la quantité de commande d'injection de carburant basée sur la pression de carburant détectée, si un traitement arithmétique de la pression de carburant détectée lors du premier instant est terminé plus tôt que le deuxième instant.

15

14. Procédé selon revendication 13 **caractérisé par** l'étape consistant à :

déterminer laquelle de la pression de carburant détectée et de la pression de carburant estimée doit être utilisée, basée sur un premier temps (T1) à partir du premier instant (t1) au deuxième instant (t2) et sur un deuxième temps (T2) nécessaire au traitement arithmétique.

20

15. Procédé selon revendication 14, **caractérisé par** l'étape consistant à :

calculer la quantité de commande d'injection de carburant utilisant la pression de carburant détectée, si le premier temps (T1) est supérieur au deuxième temps (T2).

25

16. Procédé selon revendication 12, **caractérisé par** l'étape consistant à :

déterminer laquelle de la pression de carburant détectée et de la pression de carburant estimée doit être utilisée pour calculer la quantité de commande d'injection de carburant, basée sur une vitesse de rotation du moteur (1).

30

17. Procédé selon revendication 16, **caractérisé par** l'étape consistant à :

calculer la quantité de commande d'injection de carburant utilisant la pression de carburant détectée, si la vitesse de rotation du moteur (1) est inférieure à une valeur prédéterminée.

35

18. Procédé selon revendication 12, **caractérisé par** l'étape consistant à :

calculer la pression de carburant basée sur un état de fonctionnement d'une pompe (7) d'alimentation du carburant dans la ligne d'accumulateur (14) et sur un coefficient d'élasticité volumique du carburant.

40

19. Procédé selon les revendications 12 à 18, **caractérisé en ce que** :

la quantité de commande d'injection de carburant est une quantité d'injection de carburant.

45

20. Procédé selon revendication 12 **caractérisé par** l'étape consistant à :

estimer la pression du carburant basée sur une quantité de carburant à alimentation forcée à l'aide d'une pompe (7) pour alimenter le carburant dans la ligne d'accumulateur (14) pendant une période allant de la détection de la pression du carburant au début de l'injection du carburant.

50

21. Procédé selon revendication 12, **caractérisé par** l'étape consistant à :

estimer la pression de carburant basée sur une quantité de carburant fuyant de la ligne d'accumulateur (14) .

55

22. Procédé selon les revendications 12 à 21, **caractérisé par** l'étape consistant à :

estimer une pression de carburant basée sur un changement de pression de carburant pendant une période d'injection de carburant.

FIG. 1

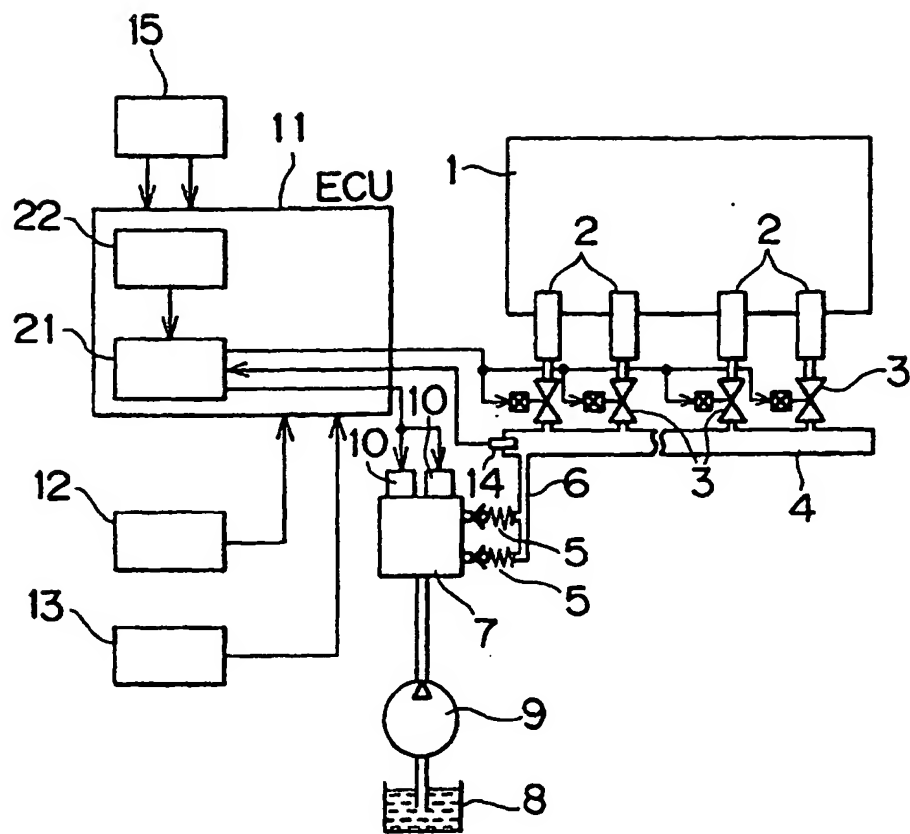


FIG. 2

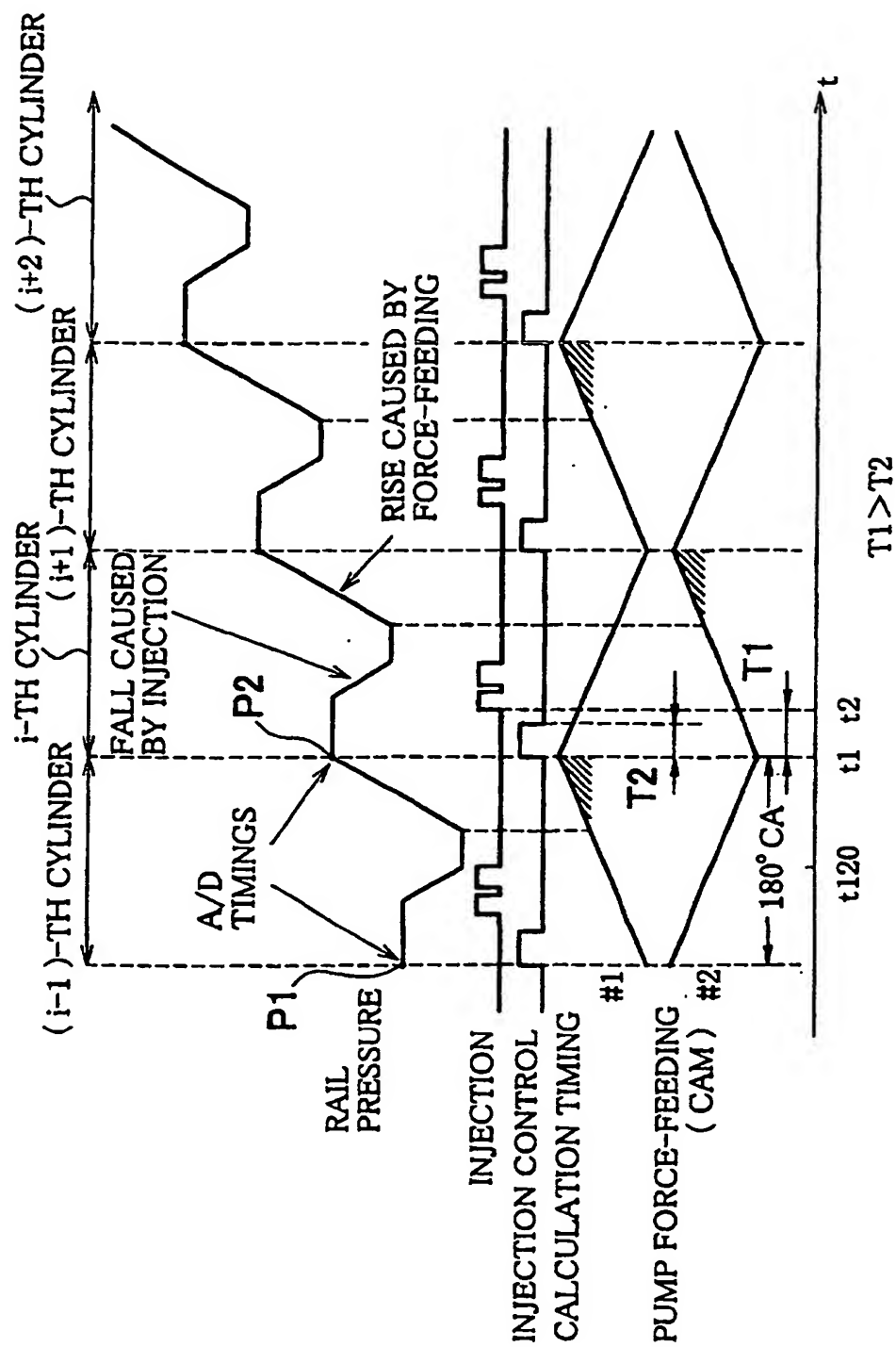


FIG. 3

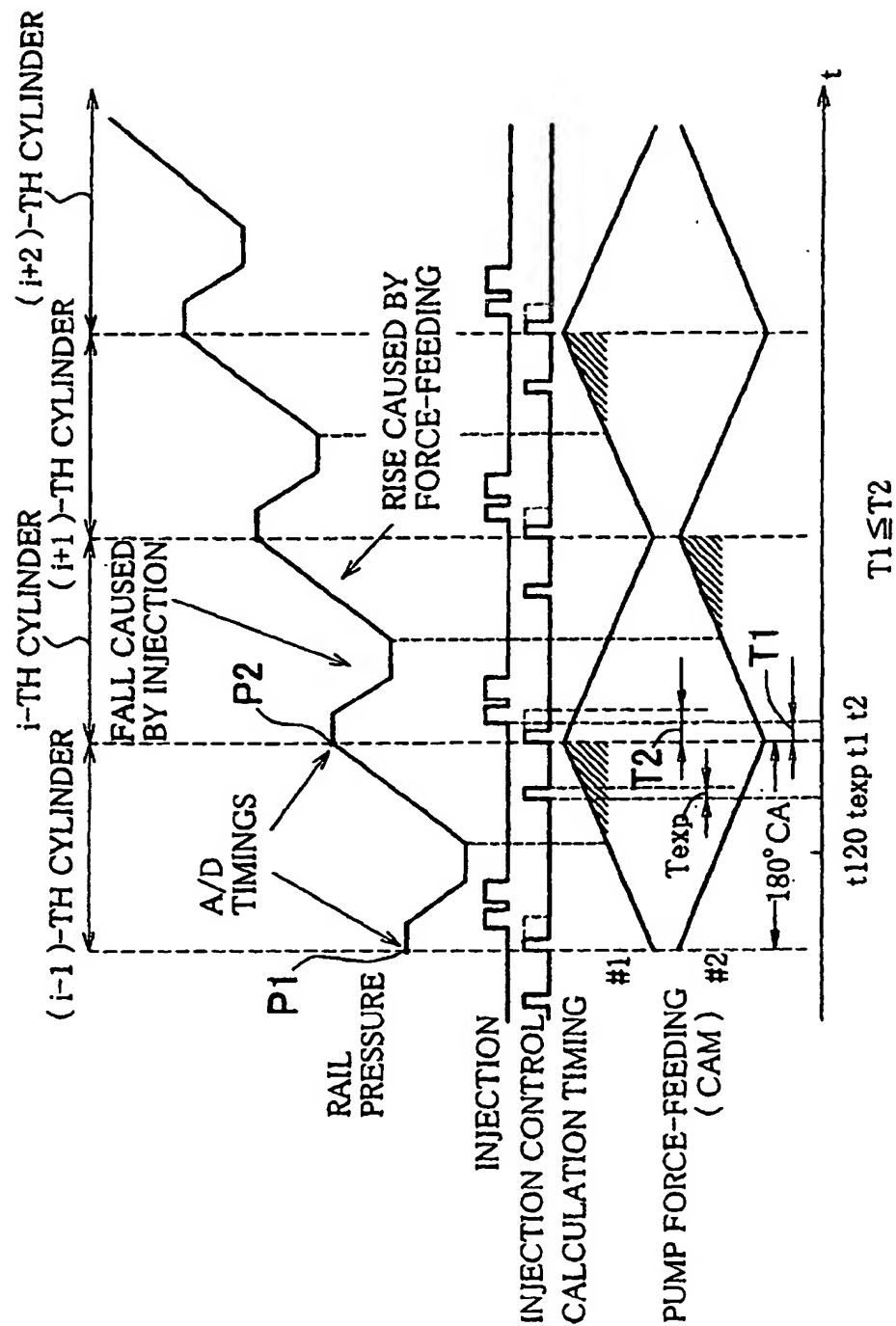


FIG. 4

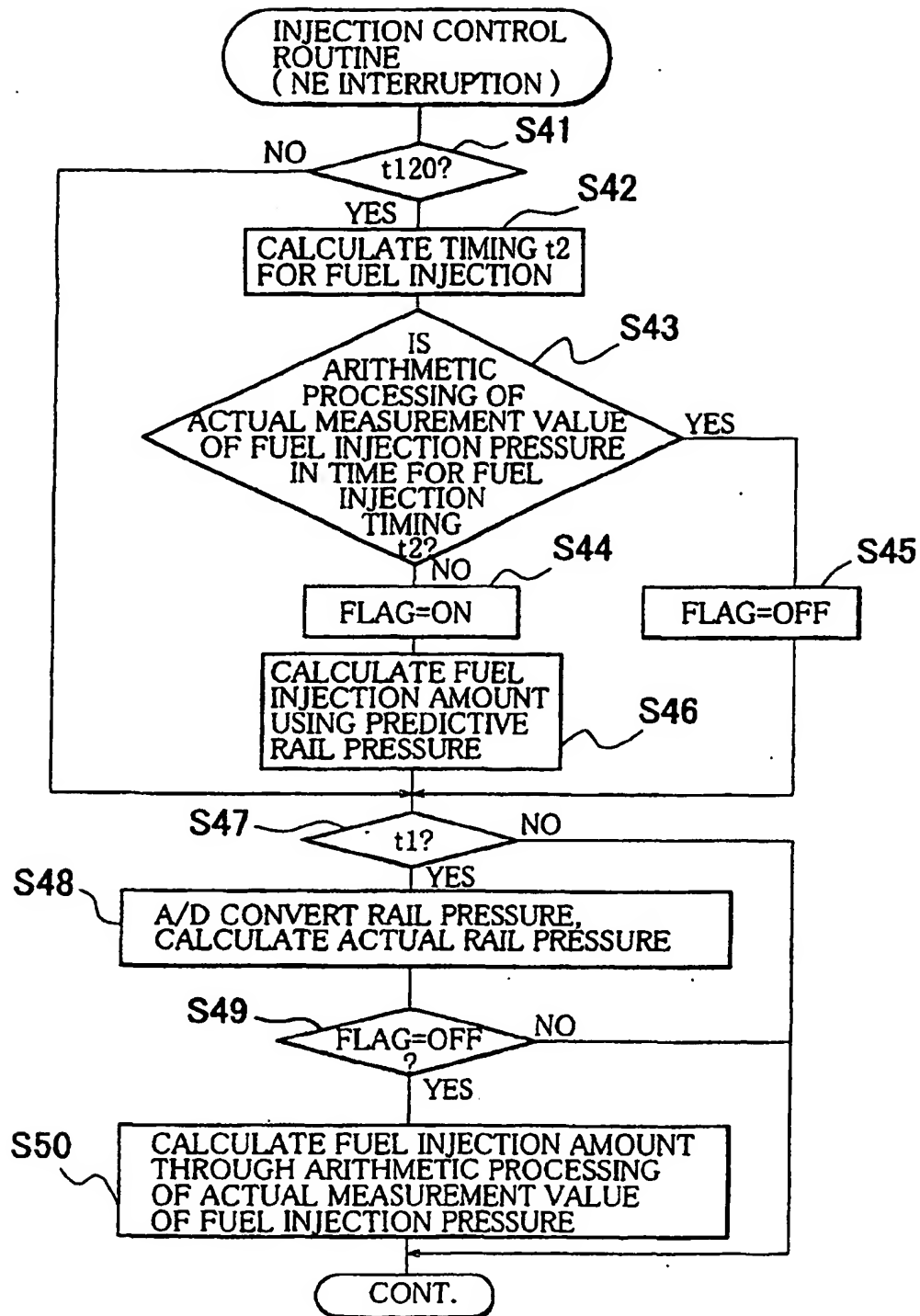


FIG. 5

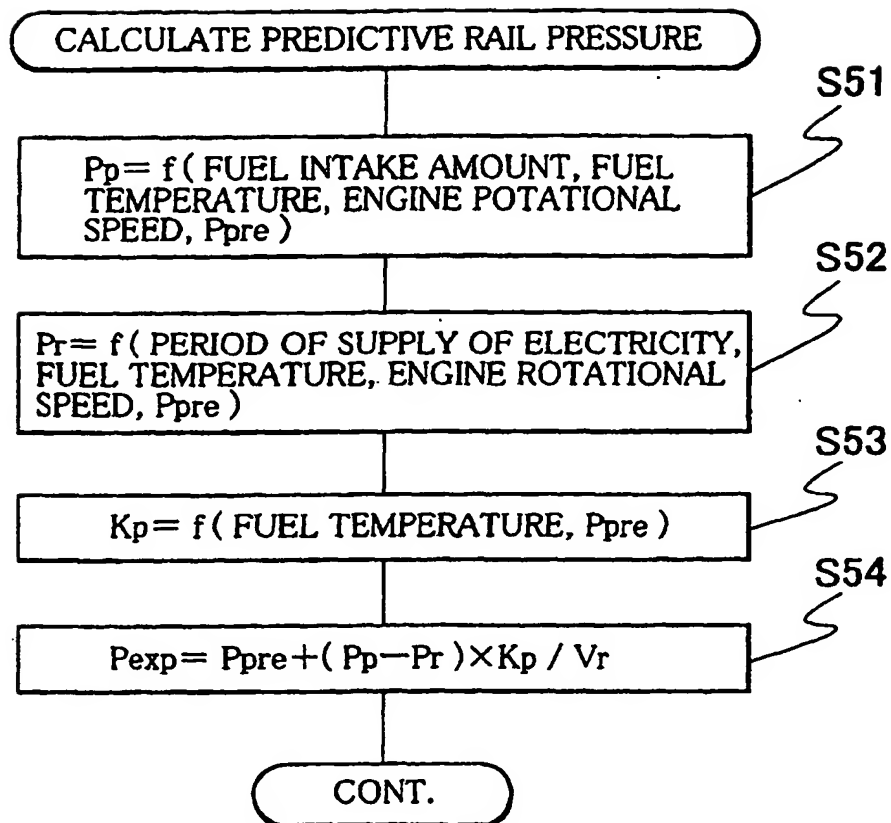


FIG. 6

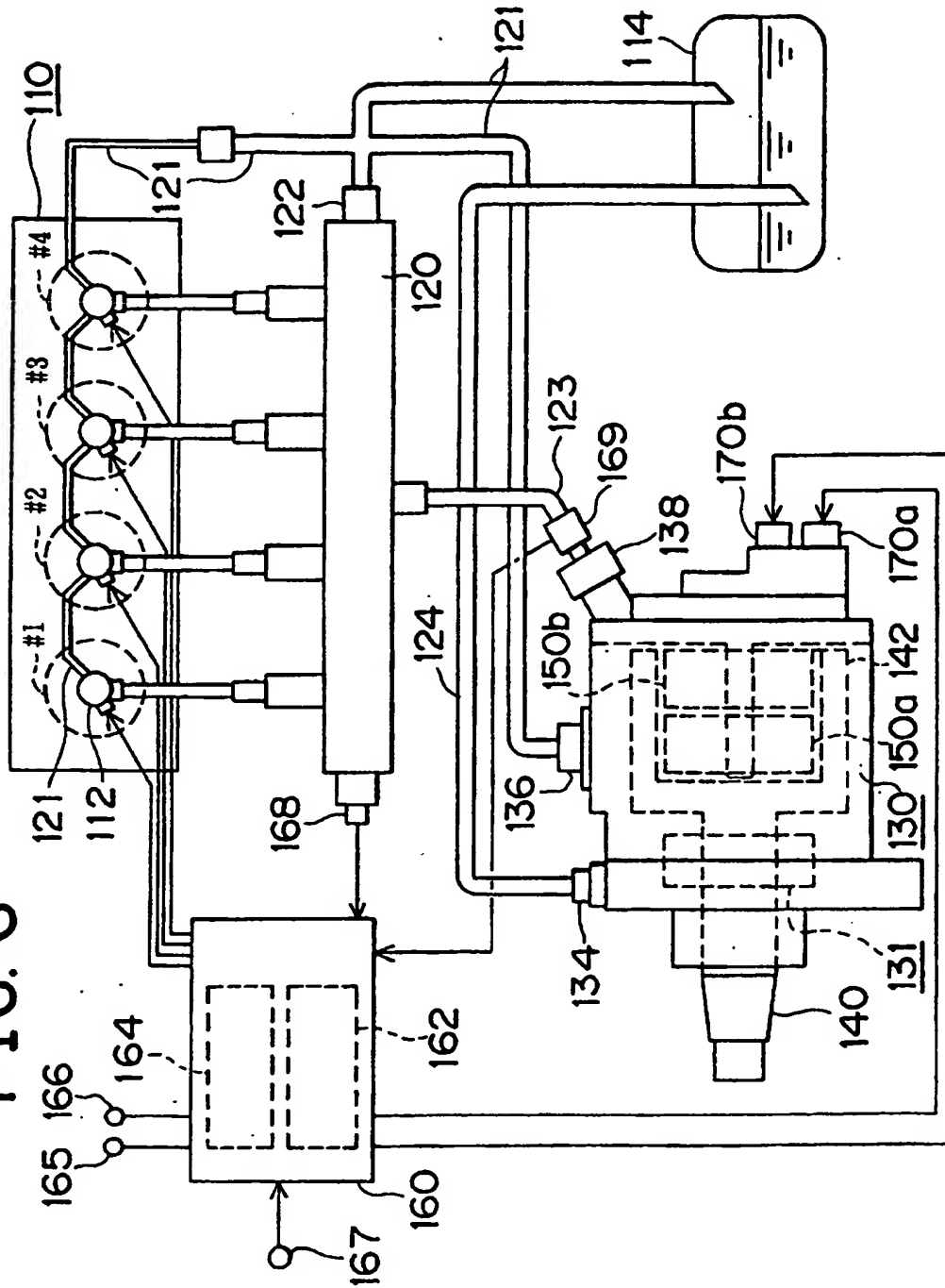


FIG. 7

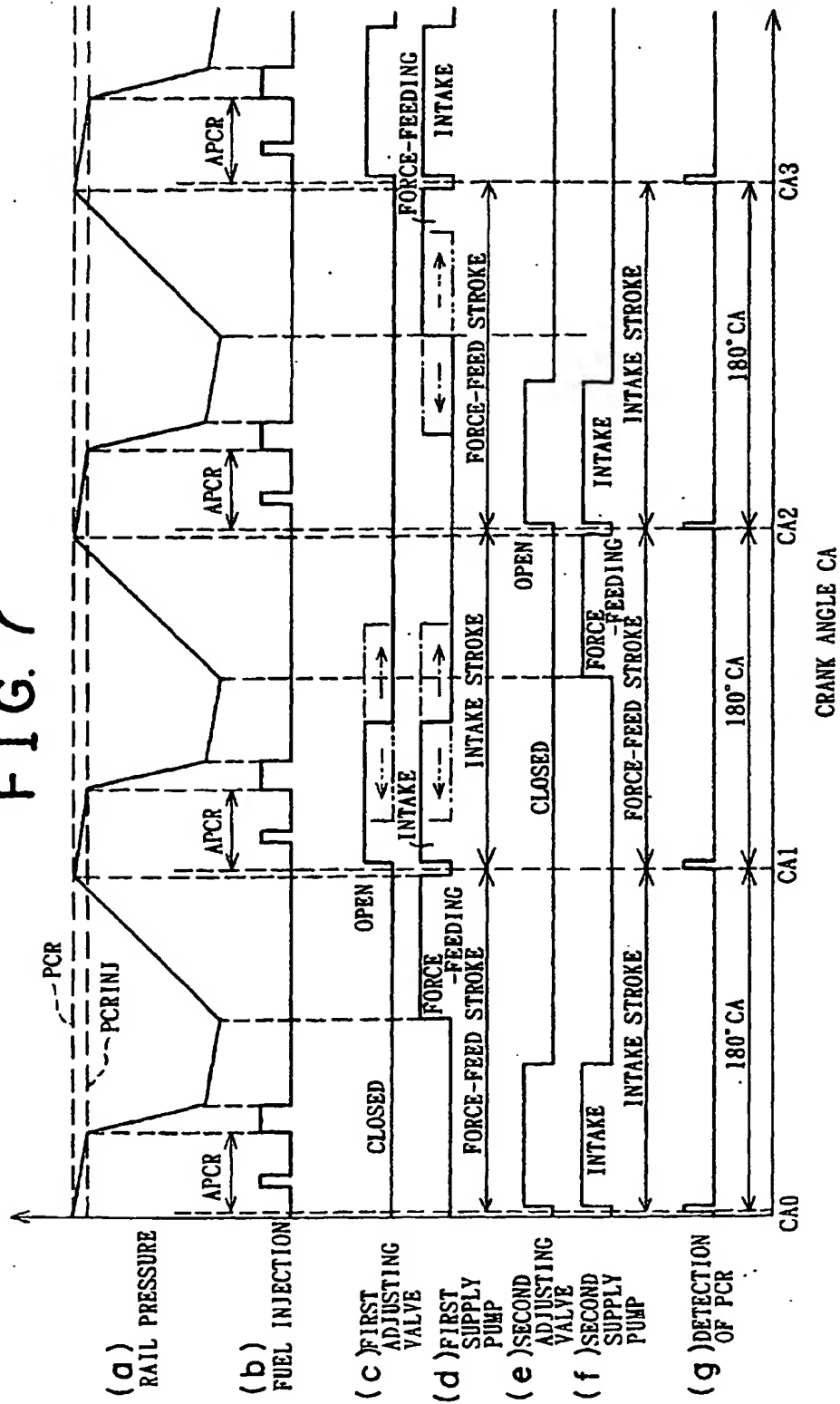


FIG. 8

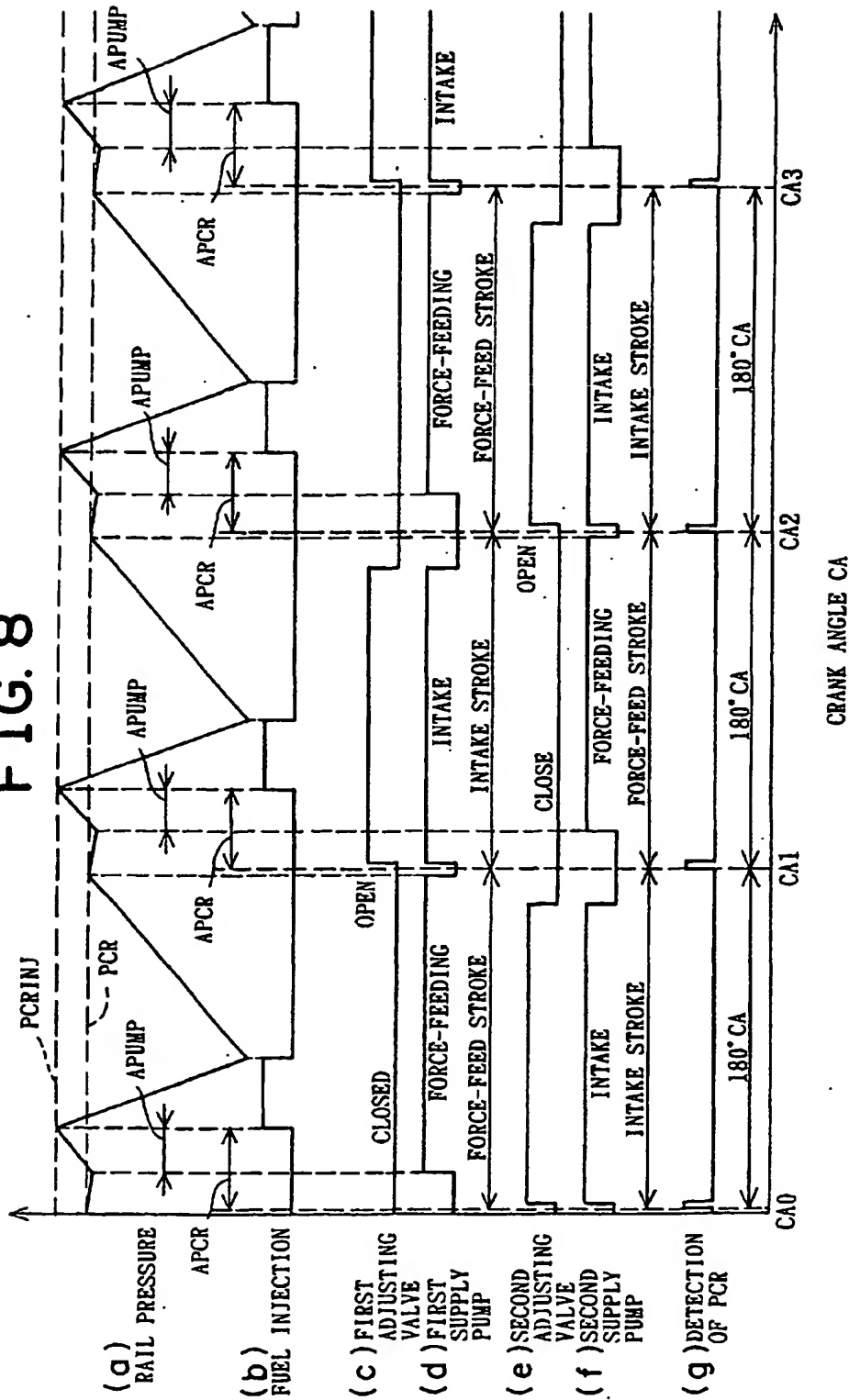


FIG. 9

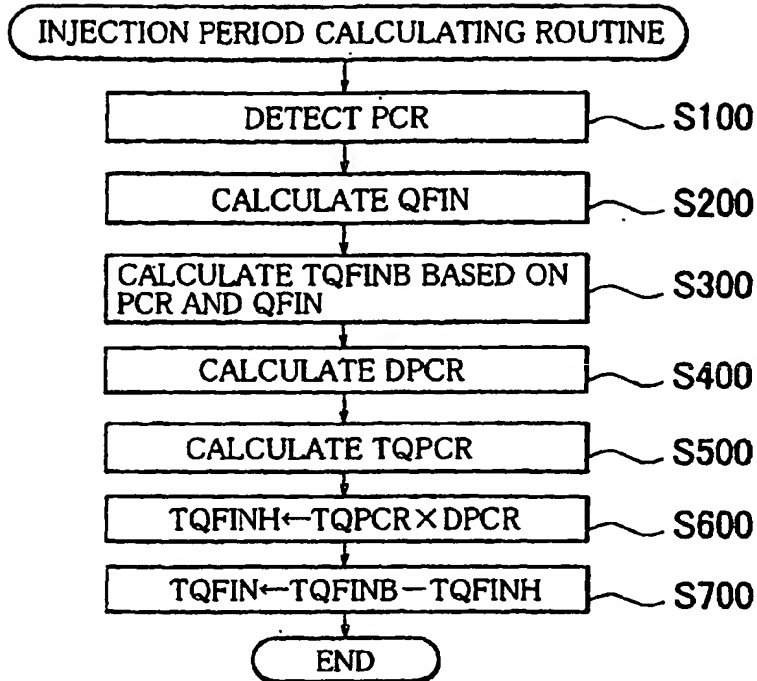


FIG. 10

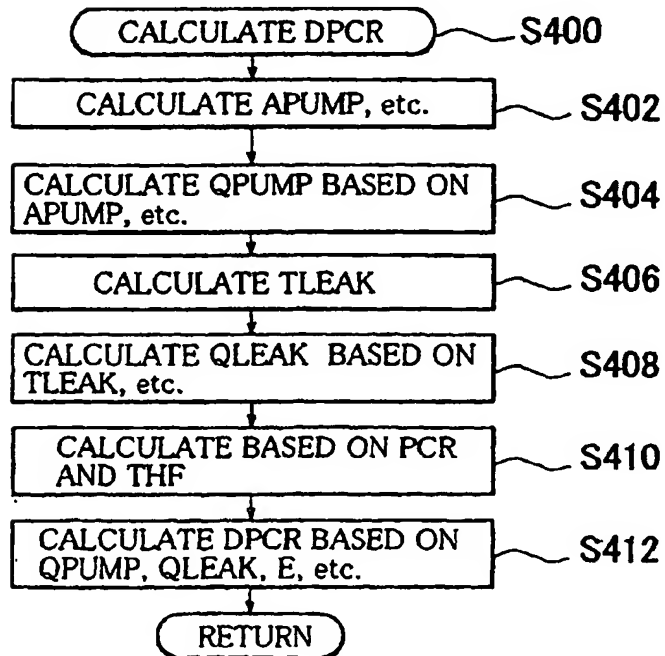


FIG. 11

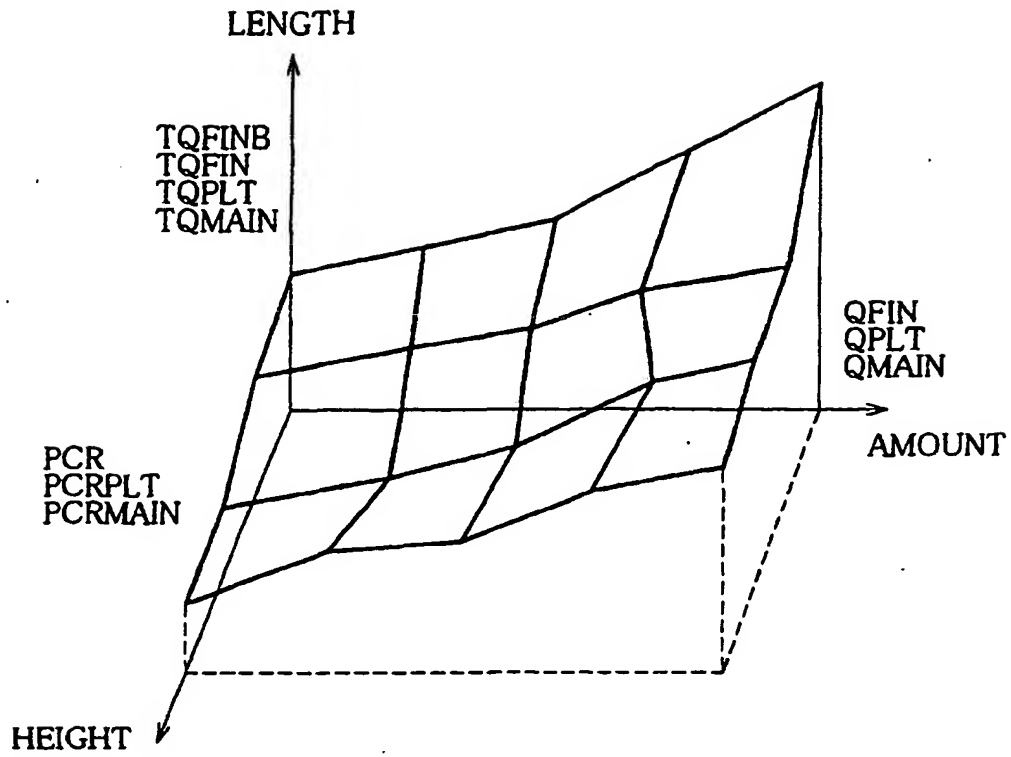


FIG. 12

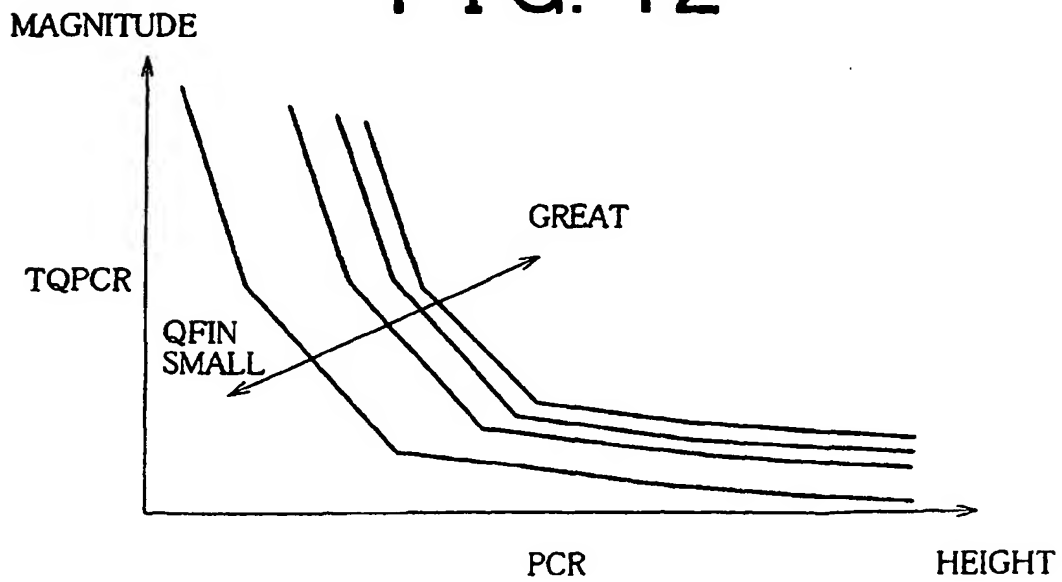


FIG. 13

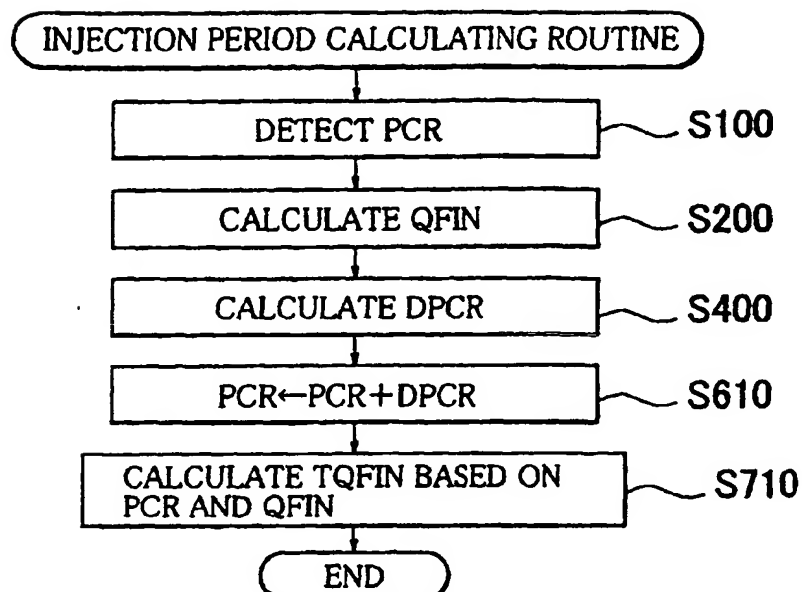


FIG. 14

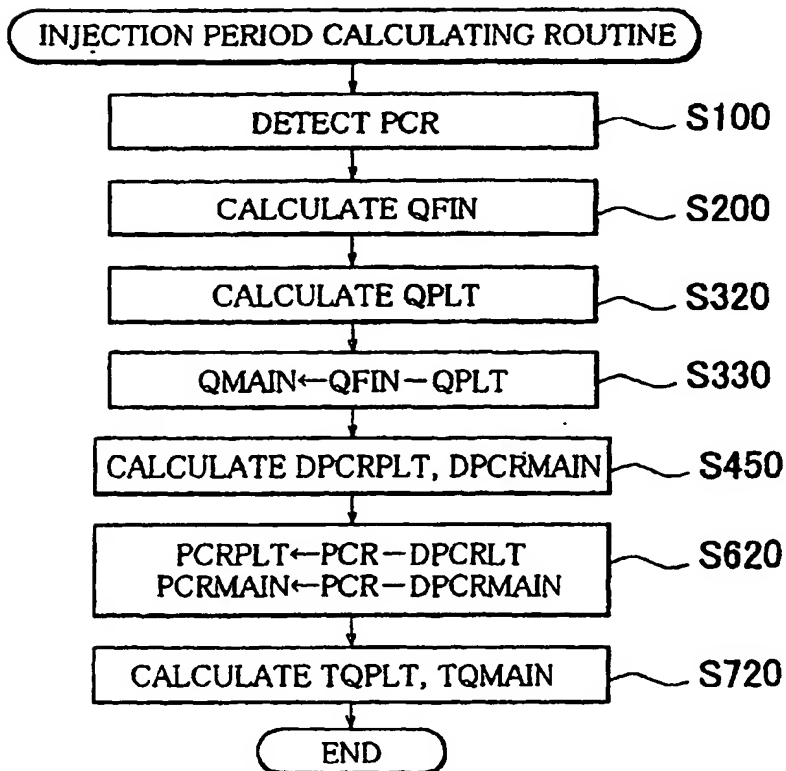


FIG. 15

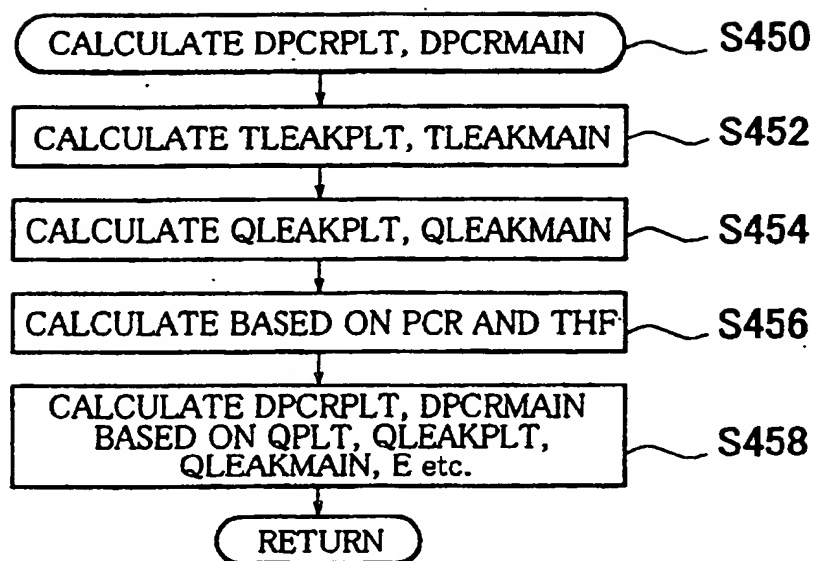


FIG. 16

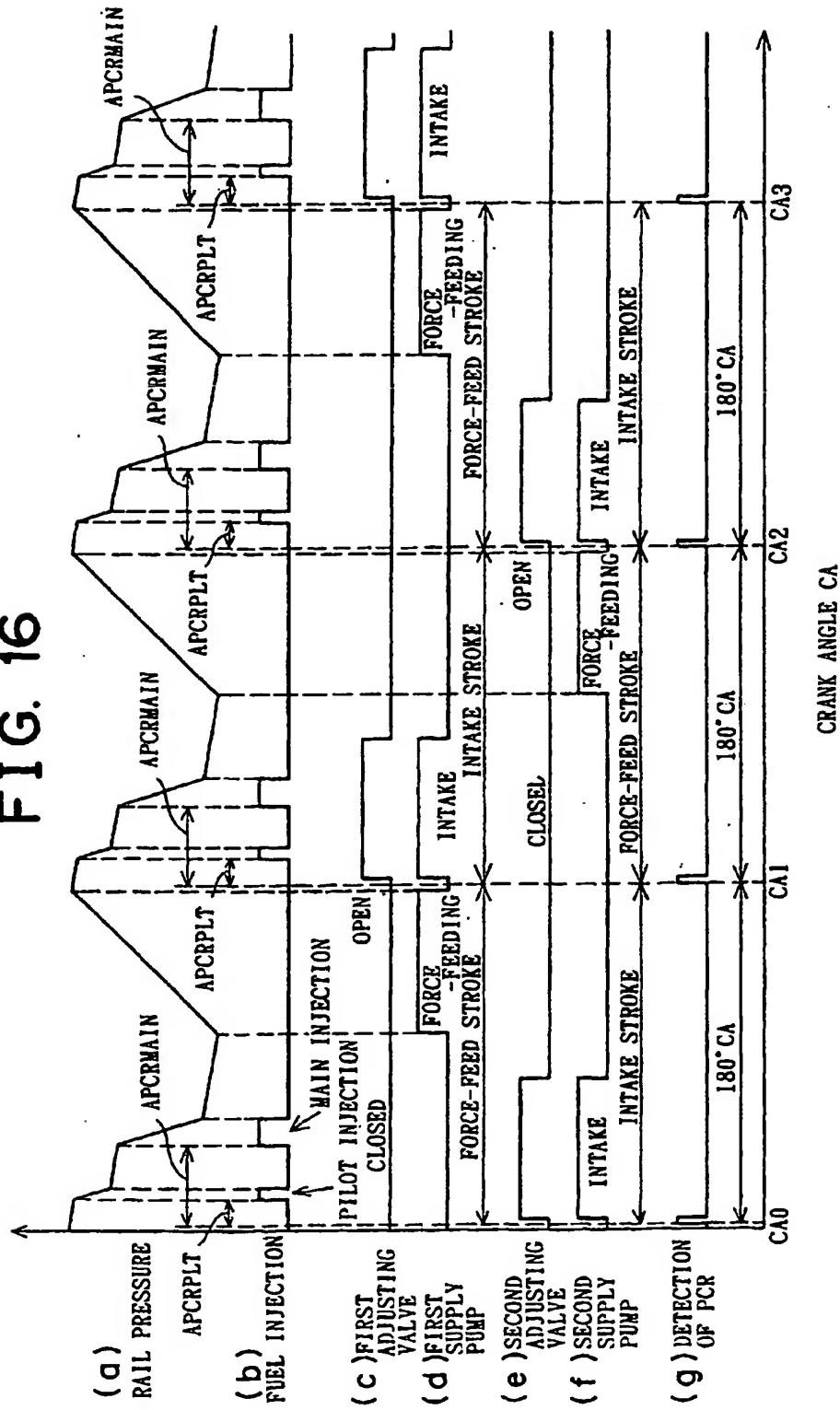


FIG. 17

